METAL PROGRESS

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Metal Progress

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American Society for Metals Technical Program

Chicago, Oct. 20 through 24. Sessions at both Palmer House and at International Amphitheatre

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Tempering Effects and the Mechanical Equation of State, by J. C. Fisher and C. W. MacGregor, Massachusetts Institute of Technology (18-170)

An Investigation of Tempered Chromium-Silicon Spring Steel, by H. J. Elmendorf, American Steel & Wire Co. (18-169)

2:00 P. M.—International Amphitheatre

The Induction Hardening of a Quality Controlled Iron, by C. F. Walton, Meehanite Metal Corp., and H. B. Osborn, Ohio Crankshaft Co. (18-171)

Some Factors Affecting the Induction Hardening of an Alloy Cast Iron, by J. R. Sloan and R. H. Hays, Caterpillar Tractor Co. (18-172)

A Study of the Metallurgical Characteristics of Three Induction-Hardened Steels Heated at Various Rates, by J. W. Poynter, Wright Field (18-173)

Tuesday, Oct. 21

Session I

10:00 A. M.—Ballroom, Palmer House

The Dimensional Stability of Steel—Part II—Further Experiments on Subatmospheric Transformations, by S. G. Fletcher, Latrobe Electric Steel Co., and B. L. Averbach and M. Cohen, Mass. Inst. of Tech. (18-174)

The Dimensional Stability of Steel—Part III—Decomposition of Martensite and Austenite at Room Temperature, by B. L. Averbach and M. Cohen, Massachusetts Institute of Technology, and S. G. Fletcher, Latrobe Electric Steel Co. (4-107)

Acicular Transformations in Alloy Steel, by E. A. Loria, Mellon Institute of Industrial Research (4-108)

Session II

10:00 A. M.—Red Lacquer Room, Palmer House

Beryllium in Magnesium Casting Alloys, by J. R. Burns, Wright Field (3-245)

The Heat Treatment and Properties of Some Beryllium-Nickel Alloys, by W. Lee Williams, U. S. Naval Engineering Experiment Station (18-175)

Stretching Characteristics of Aluminum Alloy Sheet, by J. M. Taub, Los Alamos Scientific Lab. (19-273)

2:00 P. M.—International Amphitheatre

The Location of Alloying Metals in White Cast Iron, by H. A. Schwartz and James Hedberg, National Malleable & Steel Castings Co. (4-109)

Graphitization of Steel at Elevated Temperatures, A. B. Wilder and J. D. Tyson, National Tube Co. (4-110)

Concept of the Hydrogen Potential in Steam-Metal Reactions, by Carl A. Zapffe, Baltimore (4-111)

Abstracts of the papers listed on this page are contained in the September issue of Metals Review (Review of Current Metal Literature). Annotation numbers are given for each title so abstracts can be readily found. For instance, designation 3-244 corresponds to the abstract with that number.

Wednesday, Oct. 22

8:00 A. M.—Palmer House

CHAPTER CHAIRMEN'S BREAKFAST

10:00 A. M.—Ballroom, Palmer House

A.S.M. ANNUAL MEETING

Edward de Mille Campbell Memorial Lecture, by A. B. Kinzel, Electro Metallurgical Co.

12:00 Noon—Palmer House

COLLEGE ALUMNI LUNCHEONS

2:00 P. M.—International Amphitheatre

Cast Heat Resistant Alloys of the 26% Cr, 20% Ni Type—Part I, by H. S. Avery and C. R. Wilks, American Brake Shoe Co. (3-246)

The Cobalt-Chromium J Alloy at 1350 to 1800° F, by N. J. Grant, Massachusetts Institute of Technology (3-247)

Metallography of Hot-Dipped Galvanized Coatings, by D. H. Rowland, Carnegie-Illinois Steel Corp. (11-128)

8:30 P. M.—Palmer House

ATOMIC ENERGY PROGRAM

Auspices Atomic Energy Commission

Uranium and Other Metals of Nucleonic Importance, by John Chipman, Massachusetts Institute of Technology.

Metallurgical Requirements of Atomic Energy and Power Production Programs, by Walter H. Zinn, Director Argonne National Laboratory.

Thursday, Oct. 23

10:00 A. M.—International Amphitheatre

Mechanical Properties of Metals at Low Temperatures; A Survey, by L. Seigle and R. M. Brick, University of Pennsylvania (3-248)

Influence of Metallurgical Factors on the Mechanical Properties of Steel, by S. A. Herres and C. H. Lorig, Battelle Memorial Institute (3-249)

The Fatigue Strength of Binary Ferrites. by E. Epremian, General Electric Co., and E. F. Nippes, Rensselaer Polytechnic Institute (3-250)

12:00 Noon—Palmer House

CANADIAN LUNCHEON

2:00 P. M.—International Amphitheatre

The Bend Test for Hardened High Speed Steel, by A. H. Grobe and G. A. Roberts, Vanadium-Alloys Steel Co. (9-104)

Effects of Grinding on Physical Properties of Hardened Steel Parts, by H. E. Boyer, American Bosch Corp. (20-461)

Recrystallization as a Measurement of Relative Shot Peening Intensities, by K. B. Valentine, Pontiac Motor Div., General Motors Corp. (19-274)

7:00 P. M.—Ballroom, Palmer House

A.S.M. ANNUAL BANQUET

Friday, Oct. 24

10:00 A. M.—International Amphitheatre

Macro-Segregation in Some Alloy Steel Ingots, by J. W. Spretnak, Carnegie Institute of Technology (2-193)

The Distribution of Oxygen and Nitrogen in an Alloy Steel Ingot, by C. F. Sawyer, Vanadium-Alloys Steel Co., J. W. Spretnak and G. Derge, Carnegie Institute of Technology (4-112)

Multiple Correlation Applied to Steel Plant Problems, by W. T. Rogers, National Tube Co. (11-129)

2:00 P. M.—International Amphitheatre

Detection of As-Cast Austenite Grain Size in Heat Treated Cast Alloy Steels, by E. A. Loria, Mellon Institute of Industrial Research (11-130)

The Effect of Silicon on the Properties of Cast Carbon and Carbon-Molybdenum Steels, by N. A. Ziegler, W. L. Meinhart and J. R. Goldsmith, Crane Co. (3-251)

The Effect of Homogenization on Cast Steels, by R. J. Marcotte and C. T. Eddy, Michigan College of Mining and Technology (18-176)

Two Lecture Courses

Introductory Physical Metallurgy

Four Lectures by C. W. Mason, Cornell University.

Monday and Tuesday, Oct. 20 and 21

4:15 and 8:00 P. M.; International Amphitheatre

Copper and Copper Alloys

Three Lectures by O. W. Ellis, Ontario Research Foundation.

Wednesday, Oct. 22, 4:15 and 8:00 P. M.;

Thursday, Oct. 23, 4:15 P. M.;

International Amphitheatre

CONSOLIDATED PROGRAM

National Metal Congress

AMERICAN SOCIETY FOR METALS

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS (A.I.M.E.)

AMERICAN WELDING SOCIETY (A.W.S.)

AMERICAN INDUSTRIAL RADIUM AND X-RAY SOCIETY (X-Ray)

Saturday, Oct. 18, 1947

10:00 A.M. (in Cooperation with Case Institute of Technology) Seminar on the Fracturing of Metals; Palmer House

12:00 M. National Metal Exposition opens; International Amphitheatre

2:00 P.M. Seminar on the Fracturing of Metals; Palmer House

8:00 P.M. Seminar on the Fracturing of Metals; Palmer House

10:30 P.M. National Metal Exposition closes

Sunday, Oct. 19, 1947

9:00 A.M. Seminar on the Fracturing of Metals; Palmer House

12:00 M. National Metal Exposition opens; International Amphitheatre

2:00 P.M. Seminar on the Fracturing of Metals; Palmer House

5:00 P.M. A.W.S. President's Reception; Hotel Sherman

6:00 P.M. Seminar on the Fracturing of Metals, Informal Dinner; Palmer House

8:00 P.M. Seminar on the Fracturing of Metals; Palmer House

10:30 P.M. National Metal Exposition closes

Monday, Oct. 20, 1947

9:30 A.M. A.W.S. General Session; Hotel Sherman

9:30 A.M. A.W.S. Session on Railroad Welding; Hotel Sherman

9:30 A.M. A.W.S. Session on Air Conditioning and Refrigerators; Hotel Sherman

10:00 A.M. Technical Session; Palmer House

10:00 A.M. A.I.M.E. (Institute of Metals Division) Session on Copper and Copper Alloys; Stevens Hotel

12:00 M. National Metal Exposition opens; International Amphitheatre

12:30 P.M. A.I.M.E. (Institute of Metals Division) Executive Committee Luncheon and Meeting; Stevens Hotel

2:00 P.M. Technical Session; International Amphitheatre

2:00 P.M. A.I.M.E. (Institute of Metals Division) Session on Recrystallization and Grain Growth; Stevens Hotel

2:00 P.M. A.I.M.E. (Iron and Steel Division) Session on Metallography; Stevens Hotel

4:15 P.M. Lecture Course on Introductory Physical Metallurgy; International Amphitheatre

8:00 P.M. Lecture Course on Introductory Physical Metallurgy; International Amphitheatre

8:00 P.M. A.W.S. Awards of Prizes and Metals; Adams Lecture; Hotel Sherman

10:30 P.M. National Metal Exposition closes

Tuesday, Oct. 21, 1947

9:30 A.M. A.W.S. Session on Pressure Vessels; Hotel Sherman

9:30 A.M. A.W.S. Miscellaneous Session; Hotel Sherman

9:30 A.M. A.W.S. Research Session; Hotel Sherman

9:30 A.M. A.I.M.E. (Institute of Metals Division) Session on Light Metals; Stevens Hotel

10:00 A.M. A.I.M.E. (Iron and Steel Division) Session on Steelmaking; Stevens Hotel

10:00 A.M. Technical Session; Palmer House

10:00 A.M. Simultaneous Technical Session; Palmer House

12:00 M. National Metal Exposition opens; International Amphitheatre

12:30 P.M. A.I.M.E. (Iron and Steel Division) Executive Committee Luncheon and Meeting; Stevens Hotel

Tuesday Afternoon

2:00 P.M. Technical Session; International Amphitheatre

2:00 P.M. A.I.M.E. (Iron and Steel and Institute of Metals Divisions) Session on Surface Films and Corrosion; Stevens Hotel

2:00 P.M. A.W.S. Session on Pipe and Maintenance Welding; Hotel Sherman

2:00 P.M. A.W.S. Research Session; Hotel Sherman

2:00 P.M. A.W.S. Session on High Alloys; Hotel Sherman

4:15 P.M. Lecture Course on Introductory Physical Metallurgy; International Amphitheatre

6:00 P.M. A.I.M.E. (Iron and Steel and Institute of Metals Divisions) Cocktail Party; Stevens Hotel

7:00 P.M. A.I.M.E. (Iron and Steel and Institute of Metals Divisions) Annual Fall Dinner; Stevens Hotel

7:45 P.M. A.W.S. University Research Conference; Hotel Sherman

8:00 P.M. Lecture Course on Introductory Physical Metallurgy; International Amphitheatre

10:30 P.M. National Metal Exposition closes

Wednesday, Oct. 22, 1947

8:00 A.M. Chapter Chairmen's Breakfast; Palmer House

8:30 A.M. Industrial Gas Breakfast and Fall Meeting of the Midwest Industrial Gas Council; Stevens Hotel

9:30 A.M. A.W.S. Session on Resistance Welding; Hotel Sherman

9:30 A.M. A.W.S. Session on Cutting; Hotel Sherman

9:30 A.M. A.W.S. Session on Ship Structures Research; Hotel Sherman

9:30 A.M. X-Ray Technical Session; Hotel Morrison

10:00 A.M. Annual Meeting and Campbell Memorial Lecture; Palmer House

12:00 M. National Metal Exposition opens; International Amphitheatre

12:00 M. College Alumni Luncheons; Palmer House

2:00 P.M. Technical Session; International Amphitheatre

2:00 P.M. A.I.M.E. (Iron and Steel and Institute of Metals Divisions) General Session

2:00 P.M. A.W.S. Session on Resistance Welding; Hotel Sherman

2:00 P.M. A.W.S. Nonferrous Session; Hotel Sherman

2:00 P.M. A.W.S. Session on Ship Structures Research; Hotel Sherman

2:00 P.M. X-Ray Technical Session; Hotel Morrison

4:15 P.M. Lecture Course on Copper and Copper Alloys; International Amphitheatre

7:00 P.M. Gun Development Group Dinner Meeting; Union League Club

8:00 P.M. Lecture Course on Copper and Copper Alloys; International Amphitheatre

8:30 P.M. Atomic Energy Program; Palmer House

10:30 P.M. National Metal Exposition closes

Thursday, Oct. 23, 1947

9:30 A.M. A.W.S. Session on Low Alloy Steels; Hotel Sherman

9:30 A.M. A.W.S. Miscellaneous Session; Hotel Sherman

9:30 A.M. A.W.S. Structural Session; Hotel Sherman

9:30 A.M. X-Ray Technical Session; Hotel Morrison

10:00 A.M. Technical Session; International Amphitheatre

10:00 A.M. National Metal Exposition opens; International Amphitheatre

12:00 M. Canadian Luncheon; Palmer House

2:00 P.M. Technical Session; International Amphitheatre

2:00 P.M. X-Ray Lester Lecture and Annual Meeting; Hotel Morrison

4:15 P.M. Lecture Course on Copper and Copper Alloys; International Amphitheatre

6:00 P.M. National Metal Exposition closes

7:00 P.M. A.W.S. Annual Banquet; Hotel Sherman

7:00 P.M. Annual Banquet; Palmer House

Friday, Oct. 24, 1947

9:30 A.M. A.W.S. Session on Inert Gas Welding; Hotel Sherman

9:30 A.M. X-Ray Technical Session; Hotel Morrison

10:00 A.M. Technical Session; International Amphitheatre

10:00 A.M. National Metal Exposition opens; International Amphitheatre

2:00 P.M. Technical Session; International Amphitheatre

2:00 P.M. X-Ray Technical Session; Hotel Morrison

2:00 P.M. A.W.S. Business Session; Hotel Sherman

3:00 P.M. A.W.S. Board of Directors Meeting; Hotel Sherman

6:00 P.M. National Metal Congress and Exposition ends

A Tribute to the Chicago Chapter

This year the American Society for Metals has its annual convention and exposition in Chicago, where — 30 years ago — 44 individual members of the Steel Treating Research Society of Detroit met at the Grand Pacific Hotel and organized the Chicago Chapter. Ever since, the Chicago group has bulked large in ⊛ affairs. In 26 of the 30 years a Chicago or Calumet man has held office on the National Board of Trustees. Three Chicago men have been president. It is only fitting, therefore, that something should be said about the history of so outstanding a group.

THE FIRST, as well as the current, ⊛ exposition was held in Chicago, and as an old-timer works through the 125,000 sq.ft. of exhibition space in 1947 he will remember the Armory show of 1919, when the sale of 60-odd booths each of 10 sq.ft. seemed a big deal.

Arthur G. Henry, secretary of the Chicago Chapter at the time, was the instigator of this first show. (As a matter of precision, we should not have written "Chicago Chapter", for that was before the present national society was formed.) After attending a Foundrymen's exposition in Milwaukee earlier in the year, he felt that an exhibit should illustrate a convention the Chicago group meant to hold on the subject of heat treating methods. Fellow members on his executive committee were "completely astounded. No one of them had had previous experience with such matters. No one knew how to go about such an undertaking. There was little or no money in the treasury with which to finance the necessary preliminaries." There were all of 400 members in the entire Chicago membership. As T. E. Barker, serving then as chairman of the executive committee, later remarked, "In fact, while we did not say so, I think most of us men thought Arthur, at least temporarily, a bit off balance and if we humored him he would soon come out of it. So we did the usual thing: appointed him chairman of the exposition committee. . . .

"Well, Arthur didn't come out of it. He was the busiest man on the board until that exposition was staged in the Seventh Regiment Armory (11 months later). While there were others who helped him, to Arthur Henry belongs the credit for its great success; for it was his contagious enthusiasm, ability, and unfaltering energy that made it a wonderful achievement for a one-year-old technical society. The 'program' for the convention and exposition was printed on a single sheet of paper which, when folded four-ply, will go into a No. 10 envelope. It is quite an oddity as compared with the deluxe editions which have become common to us.

"Our first banquet was, strange to say, by far the largest of any since then, there being present 620 members and guests. It was held in the Cameo Room of the Morrison Hotel. 'Bill' Eisenman officiated as master of ceremonies with much credit to himself. John W. O'Leary, a former president of the Chicago Association of Commerce . . . was our first speaker. Addresses were also made by Dr. Henry Marion Howe, the dean of American metallurgists, and by Joseph W. Richards, professor of metallurgy of Lehigh University."

The exposition itself attracted an attendance of about 10,000, and it was said — possibly with

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Metal Progress is indebted to the following ex-officers of the Chicago Chapter for highlights on each others' ⊛ careers which have been incorporated in this article: Harry Blumberg, secretary-treasurer 1920-1922; Adam M. Steever, chairman 1928-1929; Donald L. Colwell, chairman 1930-1931; Walther Mathesius, chairman 1932; A. W. Sikes, chairman 1933; Marcus A. Grossmann, chairman 1933; Harry B. Knowlton, chairman 1935; Elmer Gammeter, chairman 1937; H. S. Van Vleet, chairman 1939; J. L. Burns, chairman 1942. Thanks also are due to W. E. (Billy) Williams and Claud S. Gordon.

exuberance — that 500 of those who came to look remained to apply for membership in the sponsoring society. Mr. Henry could feel rewarded for the fact that he frequently got no more than two hours of sleep out of the 24.

Mr. Henry seems to have been an enthusiast for the little technical club whose secretaryship he assumed the year before. He not only put in a total of seven years as secretary, but he also for two of the early years managed to find desk space for its activities somewhere amid the machinery at Illinois Tool Works (where he was metallurgist), served as editor for the first issue of the *Journal,* although his name does not appear as such, and assigned one of his bright young men to read proof. A later chairman, reminiscing about his early connections with the society, said that when a speaker failed to appear it was usually Arthur Henry who got on the telephone and rustled a suitable substitute.

There were several others, of course, who were fired with promotional zeal for the infant society, and devoted a great deal of time to serving on committees, preparing papers, and buttonholing prospective members. Their motive, according to Barker's memorandum written in 1930, was a conviction "that the society would grow up to help papa".

At that time nine out of ten heat treaters thought of themselves as craftsmen skilled in the nice production of steel as resistant as the famous swords of Damascus. Chary of sharing their "recipes", and in fact having no exact formula, they were likely to instruct the novice to "heat to a full cherry red" — about as helpful as a bride finds her mother's instructions to bake a cake to a golden brown. The tenth man, like these founders of the ⊕, wanted to get together with others of like mind, pool information, and come out with some precise operations and equipment free from the inaccuracies of personal judgment. The first World War was convincing these men that victory would go to the side that could produce the best machinery in the shortest time, and that, since no factor in production was more important than heat treatment, every step toward standardization was a patriotic move.

These considerations prompted Barker, in 1916, to send in a check for membership in a Detroit organization called the Steel Treating Research Society. This group published a periodical covering the latest developments in the "art" of steel treating. The same considerations made him acquiesce a year later to Donald G. Clark's suggestion that he might chairman a chapter composed of the 40 men in Chicago, who, like himself, had joined the Detroit organization.

Forty-four men attended the first meeting of the Chicago chapter, which was held at the Grand Pacific Hotel in September of 1917. They cooperated as earnestly in devouring a sumptuous meal as they did in the idea "If you know it all, you can tell us; if you don't know it all, we can help you." By means of a mailed ballot T. E. Barker had been elected chairman; A. G. Henry secretary. The treasurer moved to another part of the country before he could attend the dinner, but since the $5 dues were simply forwarded to the parent organization in Detroit, lack of a treasurer occasioned so little embarrassment that he was not replaced!

The financial arrangement proved more satisfactory to the Detroit group than Chicago, which set up a cry of "taxation without representation" when a Detroit slate of officers for 1918-1919 included no Chicagoans. The Chicago group, 400 strong within a very few months,

Founder Members

The late T. E. Barker
Production Engineer
Miehle Printing Press & Mfg. Co.

The late Arthur G. Henry
Metallurgist
Illinois Tool Works

revolted, and one year after the first chapter meeting, met again as an independent organization called the American Steel Treaters Society. (The word "Research" was omitted from the new name, and "Steel Treating" was changed to "Steel Treaters", probably due to the phenomenal growth in membership attracted by the practical nature of the programs. Many companies had entered memberships for whole groups of their shop men.)

In September 1918, when the Chicago group first met as an independent, Mr. Barker gave a talk called "Our Vision" which was highly prophetic of the Society's future. He saw a national society composed of chapters carrying on educational activities. The findings of Steel Treaters from St. Louis to Boston would be published, "all for each and each for all", in a *Journal*, supported by advertising, "second to none as to character and quality among its class of periodicals" (we like to savor the words in these old pages). A reference library would be built up, and data sheets sent out from time to time.

Willing workers though his executive committee members were, they could not quite envision being able to accomplish all this in their spare time. They were no doubt relieved to hear, in the prospectus, about a secretary and business manager who should direct all this activity. As it turned out, this was not the least part of his vision, the outcome being the hiring two months later of one William Hunt Eisenman.

This new managing director was known to Mr. Barker as the progressive superintendent of schools in the Chicago suburb where he lived. Here was a man, Eisenman, who was teaching arithmetic by means of a grocery store set up in the school — a pretty advanced pedagogical idea for 1918. Such ideas appealed to Barker, who was looking for someone to handle an educational program for practical men. Neither was it any drawback that Eisenman happened to have an M.S. in chemistry, and had taught the subject. Nor that he seemed to have an unlimited fund of energy — an essential for anyone undertaking all the functions expected by the naive society. There was just one inconvenient angle to the post of secretary-manager — no money, either for salary or promotion. The first issue of the monthly *Journal* had been published, and the executive committee had been in need of a mathematical genius to balance:

Income: Advertising	$495.00
Treasury	50.00
	$545.00
Expenses:	
Printing and distribution of *Journal*	$895.00

Leaders in the Chicago Chapter

Year	Chicago Chapter Officers		A.S.S.T. and A.S.M. National Officers From Chicago Chapter	
	Chairman	Sec-Treas.	Name	Title
1917	T. E. Barker★	Arthur G. Henry★		
1918	T. E. Barker	Arthur G. Henry		
1919	T. E. Barker	Arthur G. Henry		
1920	F. C. Lau	Harry Blumberg	E. J. Janitzky W. H. Eisenman★ A. F. Boissoneau	1st V.P. Secretary Treasurer
1921	H. F. Wood	Harry Blumberg	T. E. Barker E. J. Janitzky	1st V.P. Director
1922	H. F. Wood	Harry Blumberg	F. C. Lau E. J. Janitzky	1st V.P. Director
1923	F. G. Wheeler	Arthur G. Henry	S. M. Havens	Director
1924	R. G. Guthrie	Arthur G. Henry	S. M. Havens	Director
1925	R. G. Guthrie	Arthur G. Henry		
1926	T. E. Barker	Arthur G. Henry	R. G. Guthrie	Director
1927	T. E. Barker	Arthur G. Henry	R. G. Guthrie	Director
1928	A. M. Steever	J. A. Comstock	T. E. Barker	Director
1929	A. M. Steever	J. A. Comstock	R. G. Guthrie T. E. Barker	Vice-Pres. Director
1930	D. L. Colwell	J. A. Comstock	R. G. Guthrie	President
1931	D. L. Colwell	J. A. Comstock	A. T. Clarage	Treasurer
1932	W. Mathesius	J. A. Comstock	A. T. Clarage	Treasurer
1933	A. W. Sikes M. A. Grossmann	J. A. Comstock	A. T. Clarage	Treasurer
1934	Harvey Anderson	Kenneth Hobbie	R. S. Archer	Trustee
1935	H. B. Knowlton	Kenneth Hobbie	R. S. Archer W. Mathesius	Vice-Pres. Trustee
1936	J. A. Calef	Kenneth Hobbie	R. S. Archer W. Mathesius	President Trustee
1937	Elmer Gammeter	Kenneth Hobbie	R. S. Archer	Trustee
1938	W. E. Remmers	E. A. Terwell	H. A. Anderson	Trustee
1939	H. S. Van Vleet	E. A. Terwell	H. A. Anderson	Trustee
1940	R. G. Roshong	E. A. Terwell	M. A. Grossmann	Trustee
1941	W. D. McMillan	E. A. Terwell	M. A. Grossmann	Trustee
1942	J. L. Burns	T. L. Haines		
1943	F. J. Robbins	T. L. Haines	M. A. Grossmann	Vice-Pres.
1944	J. W. Scott	L. J. Bohan	M. A. Grossmann	President
1945	H. W. Highriter	L. J. Bohan	M. A. Grossmann	Trustee
1946	H. L. Geiger	A. A. Engelhardt		
1947	A. S. Jameson	A. A. Engelhardt		

★Founder Members, American Society for Metals.

Prepayment of dues by members eager to get the *Journal* had pulled them through, but they did not see their way clear to a munificent salary. Privately the members of the executive committee pledged themselves to see to it that the secretary-manager should be paid — to him they put the proposition that among his other duties he should include the one of making the Society pay for itself — and himself.

Another applicant for the job was said to have presented a staggering list of "essentials" in the way of equipment and assistance. "Bill" Eisenman was more modest. At the dinner meeting when he was introduced, in December, 1918, he said:

"I have examined your affairs. I have unlimited confidence in the future development of your Society, so much so that I shall be glad to cast my lot with yours and let my salary depend upon the results attained, you to name it. The work appeals to me and I feel that I can contribute largely to the realization of the objects which you have in view."

Certainly, 1919 was a busy year. While Arthur Henry was working on his wild scheme of an exposition for the fall, Bill Eisenman was building up chapters in other localities. His first venture, typical of many others, was a trip to Cleveland, accompanied by his amiable wife, still a bit dazed over the idea of giving up a secure though modest future as a superintendent of schools for the hazards of the new career. After some scouting Bill invited W. S. Bidle and a few other Cleveland men in the metal industry to dinner, where he sold them on forming a chapter. This was the easiest part of the foray for Bill, who really likes to talk to people, who really likes a party, and whose earnest enthusiasm is contagious. Two days later the first organization meeting was held, and dues were collected. Bill had to work fast, not only because he was a bundle of energy, but he had to hurry back to Chicago to round up the next issue of the *Journal*, and he had to move on to form another chapter before the dues income disappeared on the opposite side of the ledger!

The Bell-Winning Team of 1934

HARVEY A. ANDERSON
Materials Engineer
Western Electric Co.

KENNETH H. HOBBIE
Chicago Branch Manager
Driver-Harris Co.

In the course of the first three months of his career with the Chicago group — then burgeoning into a national society — Bill Eisenman organized eight chapters, and at the end of his first year, he had earned, by vote of the executive committee and his own efforts, a bonus of several hundred dollars and a 50% raise.

A national organization — distinct from the Chicago group as far as officers were concerned — was set up in 1919. T. E. Barker was elected as the first president; E. J. Janitzky as first vice-president; Arthur E. Henry as secretary; and A. F. Boissoneau as treasurer. Other directors came from chapters other than Chicago. Since that time there have been only four years when there was no Chicago man on the national board.

In 1919 also, Barker was invited by Col. A. E. White to meet with the president of the Detroit organization with a view toward ironing out misunderstandings. Colonel White was a member of both, and decried the duplication of effort which was contrary to their fundamental thesis. After many meetings to debate such problems as allocation of dues paid to this or to that society, the

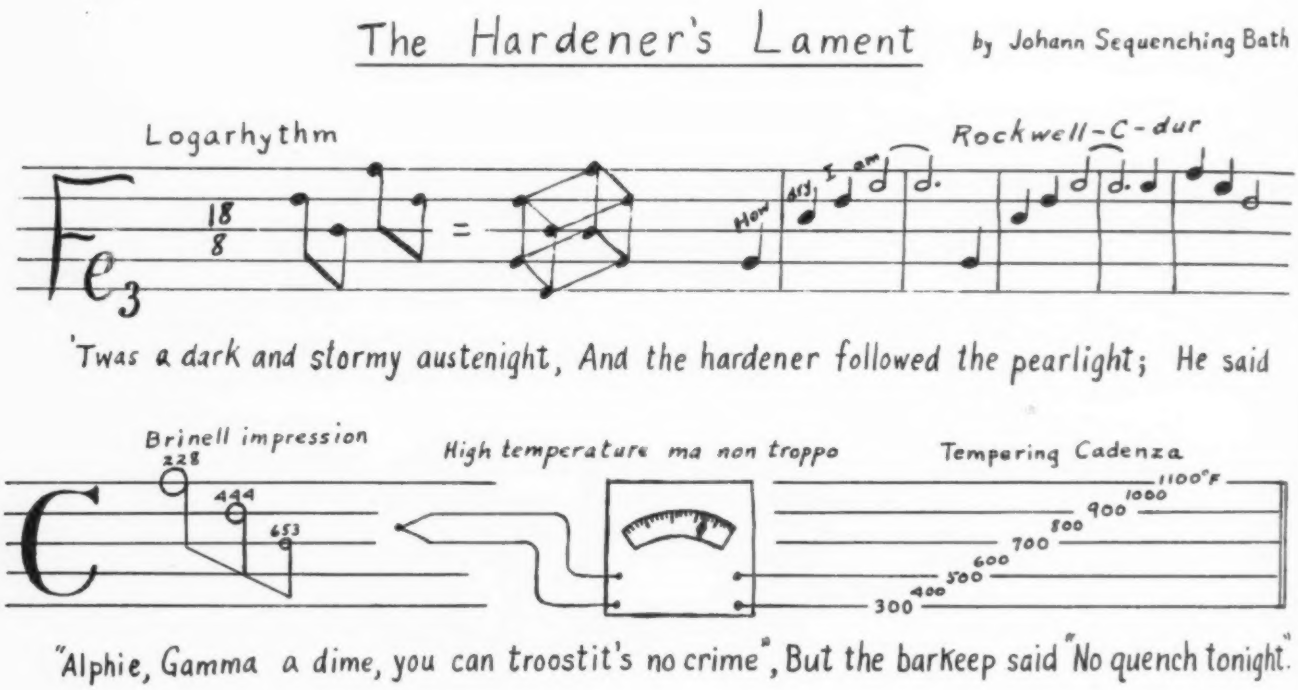
members of the amalgamation committee came to an agreement. To the satisfaction of both sides, the name of the society was also compounded, and became the American Society for Steel Treating. Neutral territory in Cleveland was chosen for national headquarters of the 27 chapters.

The Chicago Chapter likes to think of itself as a pioneer in the affairs of the Society. It was indeed the first of the chapters to inaugurate educational courses — in 1920 three courses were offered at Armour and at Lewis Institute. It was the first to hold sectional meetings, in 1923. Under the chairmanship of A. W. Sikes, in 1933, the chapter began to broaden its scope from strictly ferrous to the entire field of metallurgy.

and throw it in a tub of brine of a sufficient density to float one Idaho potato before being baked and containing one piece of good grade all-wool piano felt so as to prevent the tool's losing its temper when it strikes the bottom of the tub."

Another pleasant custom inaugurated by the Chicago Chapter was extension of the June meeting into an all-day affair featuring highly organized games. In Chicago the picnics were for some years held at a memorable place called the Hartmann House, where Bob Guthrie (later national president) was said to have distinguished himself as a pitcher of a shine-ball, and a piece of 0000 polishing paper was found in his glove.

The social angle seems to have come to play



A number of prominent metallurgists later elected to presidency of the ⊕ were invited to speak to the Chicago chapter in the early days. In 1921 Zay Jeffries was applauded for his complete mastery of the subject of "New Theory of Hardening", which he presented in a pleasing and entertaining manner. In 1923 James P. Gill made the definite statement to the group that "goats have nothing to do with the heat treatment of toolsteels, even though they be fed on green ferns grown on the hillside among the tall and stately cypress trees." He also pooh-poohed the theory that an approved tempering would be to "heat it up until it shows a color comparable to that of a bale of rye straw grown on George McNally's farm, which is located on the N.E. ¼ of the S.W. ½ of Section 23, north range 13, County of Whistleville, N. D.,

an important part in the Chicago Chapter following the war years — possibly as a relief from the earnest business of organization. When asked for reminiscences of their terms of office, more than one old-time secretary or chairman mentions the annual golf tournament, or the Ladies' Nights. Harry B. Knowlton, 1935 chairman, whose connection with the Chicago Chapter runs back to 1920, claims that much of the success of the meetings from that day to this has been due to Billy Williams, official host, who greets them as they come in the door.

It must have been a privilege indeed to be asked to serve on the executive committee, which met at frequent intervals. Very fine beer was served at one favorite meeting place, and at the Swedish Club there was Swedish punch and *aquavit,* said

to have inspired meetings that were "always very free and at times bordering on the hilarious". At this same Swedish Club there was a large map of the Baltic area which caused Walther Mathesius, 1932 chairman, master of "fascinating vocabulary and clarity of expression", to deliver travelogues on the time when he ran away and shipped as cabin boy on a German ore vessel going from Hamburg to northern ports. Business that night was dispatched quickly!

Another highly entertaining chairman was W. D. McMillan (1941), whose "sophisticated humor made him a delightful conductor of meetings". During his regime attendance at dinner meetings rose to an average of 200. Possibly he was the author of a song, The Hardener's Lament, which was produced around this era of the chapter's history.

One of the memorable addresses given before the Chicago Chapter was that on "Age Hardening of Metals", presented in 1939 by Kent R. Van Horn. Dr. Van Horn recalls that he was approached as long as two years before, and the point was stressed that he should give a highly technical talk which should still have popular appeal! At intervals, as members of the Chicago executive committee were passing through Cleveland, they would call him on the phone, or look him up for lunch, and remind him of his responsibility, now 11 months off, now 8 months off. He began to wear furrows in his youthful brow, puzzling how to popularize age hardening. Finally the idea came from a friend who told him how Sally Rand had her own heat treating problems, arising out of the fact that her bubbles would burst under the hot spotlights. A special rubber bubble had been developed for her, and a number of photographs in her new wardrobe came under Van Horn's appraising eye. The result was a technical lecture, with slides occasionally superimposing age-hardening curves on Sally's contours. The talk had all the suspense of a romantic novel, and the audience gave Dr. Van Horn close attention.

For some years following its early and rapid growth, the membership remained fairly static at close to 500. Attendance was always good, however — Harry Knowlton recalls that it never fell below 50, even on the night when he himself was the speaker and the thermometer stood at 19 below zero. In panicky 1932, in spite of the prevailing low in production and business morale, the chapter began to look forward to its "600 Night". Walther Mathesius, then chairman, does not attribute this to his political beliefs, as he remembers he had "absolutely no success whatever in persuading friends to vote for Herbert Hoover again for President". Instead, he believes "it was accomplished — at least partly — because of our determination to turn away from the financial support presumably available through so-called 'supporting memberships' by various business concerns, and to concentrate instead on a solicitation of individual members, and of so shaping the Chapter's program that it appealed to a large percentage of present and prospective members — especially after we learned to supplement this phase of our activity by a carefully worked out plan of continued personal contact between the members of the Chapter committees and the membership at large."

Leaders in the Calumet Chapter

Year	Chairman	Sec-Treas.
1937	H. B. Wishart	O. W. McMullan
1938	O. W. McMullan	D. L. Simpson
1939	F. S. Sutherland	C. E. Chapman
1940	C. E. Chapman	K. F. Schauwecker
1941	D. E. Wilson	C. A. Walther
1942	J. E. Drapeau	E. P. Epler
1943	E. P. Epler	H. H. Feierabend
1944	H. H. Feierabend	I. N. Goff
1945	M. A. Jones	R. B. Lucas
1946	I. N. Goff	Philip H. Parker
1947	R. B. Lucas	W. S. Lienhardt

A.S.M. National Officer From Calumet Chapter
1943, 1944, Erle G. Hill

In 1934, with Harvey Anderson as the dynamic chairman who goaded a willing executive committee, and Kenneth Hobbie as the conscientious secretary-treasurer (who would fly hundreds of miles from a business trip in order to attend each meeting, and who contributed his business administrative abilities to the affairs of the Chapter), the membership made its greatest increase for one year. For these "outstanding activities of the Chapter, as well as its contribution to the success of the Society" (in the words of the citation) Chicago was awarded the coveted President's Bell. From that time on the membership continued to grow, except for a temporary decline in 1937 when some members were transferred to the newly-formed Calumet Chapter, embracing members in the Hammond, Gary, and East Chicago area. However, the Chicago Chapter was actively interested in this promotion, as it was felt that the district was too large to be served adequately by one central group. Soon the membership was back to normal, and more.

Today the Chicago Chapter is not only the second oldest, but the second largest, boasting 1500 members. Long life to it; may it continue to provide new and progressive ideas! D.F.T.

Pages From a Biographical Dictionary

William Hunt Eisenman

Secretary A.S.M. (1917 —)

Biographical Appreciation by Dorothy Frances Thum

NO ONE could look less like an educator than Bill Eisenman. You don't catch him smoking a meditative pipe in his book-lined study; when he reads, it's the newspaper. You don't find him — away from the office — absorbed in a technical discussion with his colleagues. Instead you find him hauling crowds of friends around his farm on a hay-ride, circulating about making everyone feel at home, swapping jokes whose age varies from one hour to one century.

He doesn't even look undernourished. He should, in view of the sorry financial status of most teachers. The fact is, he looks very like a prosperous business man. And the fact is, he has made a successful business of education.

In his early youth, he followed the conventional pattern. William Hunt Eisenman was born on July 7, 1886, in the small Ohio village of Jamestown, some 25 miles east of Dayton. His advanced education was at Kenyon College in Ohio (Ph.B.) with postgraduate work (Master of Science in Chemistry) at Stanford University, Morningside College in Iowa and Ohio State University. He began work as a chemistry instructor at Racine College (Wis.). Still a young man when he became superintendent of public schools in Elmhurst, Ill., he quickly made a reputation by introducing progressive ideas into the school system. He also had the good fortune to meet his future wife, Mildred Randle, one of the teachers.

Much as he was interested in his work, he realized that he could never expect to earn very much as a superintendent of schools. ($5000 was the salary offered him by the board of education at Nashville, Tenn.) So — opportunity offering — he decided to take a chance on a school for *adult* education, peculiar in that all the students were likewise teachers. Members of the American Society for Steel Treaters (as this Chicago "school" was then called) were all metallurgists who were willing to share the findings of their research or practice in return for similar help from the next fellow. At the time Bill took a flyer in the embryo Society (1917), the financial picture was even less attractive than for most colleges today. The only favorable factor was the complete lack of physical plant requiring maintenance.

Bill undertook the job of making this school pay for itself, and from that day to this, it has seen only one red statement, in the mid-depression year of 1932, thus building up its resources to a level at once the envy and despair of other engineering societies the world over. Hired to manage one desk, one stenographer, and 400 student-teachers, he now presides over two large buildings, personnel numbering 40, and some 20,000 members scattered over this and other countries.

What is the secret of this success? The answer is probably simple: By unremitting application of business principles to education.

"Give the public what it wants and the public will buy" is a popular business principle which is not always a criterion of a college curriculum. Bill has, however, made it his business to determine and supply *services* to members. Perhaps this is best illustrated by the National Metal Exposition. It is an activity based on the fact that the A.S.M.'s large membership includes thousands of men with influence on the purchase of materials and supplies, in the organization of activities and selection of processes. What more natural than to bring these customers to business men — to their mutual benefit? So widely approved have been his "show techniques" that Wm. H. Eisenman was made president of the Association of Exhibit Managers at the first meeting in 1932, was re-elected again and again until 1946 when he was promoted to the post of general councillor.

Next secret of success is that he sees to it that accounts receivable exceed accounts payable. If an activity doesn't pay its own way, something must be done about it. There can be no little leaks, here and there, into attractive byproducts.

On the other hand, there's no disposition to avoid necessary developmental expenditures. Thus, in the early days, when he was organizing chapters, he would entertain prospective officers at the Statler Hotel or its equivalent. But the next day, when he was eating alone and in full possession of the iron constitution of youth, he ate around the corner at Thompson's, or its equivalent. *Metal Progress*, started early in the depression, lost considerable money for three years, but he held steadfast to the hope — soon realized — that this magazine would more than pay for itself, not only in dollars and cents, but also as a powerful prestige-builder for members and Society alike.

He is, indeed, remarkably persistent about carrying out an idea he is convinced is a sound one. As an example, he has kept in mind for 20 years the desirability of prompt abstracts of current engineering literature as a means of keeping the membership informed on a vast body of reading matter they could not possibly have time even to scan. In its early years *Metal Progress* included a purchased abstract service, but these got the shears in the depression years. Bill didn't forget, however, that this was a most desirable service to members, and for four years now the unique and up-to-the-minute "A.S.M. Review of Current Metal Literature" has been appearing, month by month, in *Metals Review*.

Bill attacks his job today, as he did when he began it 30 years ago, with a messianic zeal not

ordinarily devoted to just a job. What a minister he would have made! (When he started to Kenyon College this was actually his intention.) Perhaps he was attracted to the Steel Treaters Society originally by the idealism of the slogan, "Each for All and All for Each", at a time when cooperation among metallurgists was meager indeed.

At any rate, he lives his work. The story is told that when he heard of the first resignation from the Society, he spent his day off transferring from trolley car to trolley car to reach the recalcitrant and sell him on the imperative necessity to remain in the fold. He really wanted to know why the member was resigning, what was wrong with the Society, how the curriculum should be changed, and to prove that the member would lose many services to himself if he carried out his intention.

There is no one more convinced that the A.S.M. offers services more valuable than the $10 it costs than WILLIAM HUNT EISENMAN. He's completely sold on the Society himself. And as any sales manager knows, the attitude of "Here's the greatest little gadget that ever was invented, and I'm offering you the opportunity to buy it for your own good" makes all the difference between a mediocre and a good salesman.

To back up his tremendous enthusiasm Bill is lucky enough to have prodigious energy, a characteristic noticeable to even the casual acquaintance. It probably would have made him a success in whatever line of work he had elected. Many people have commented that his name, translated, means "Iron Man". We think this does his energy less than justice — he can't be worn down, it is true, but there is nothing inert about him. He can chairman meetings all day, and appear fresh at an evening function. He is never too tired to seize on a new idea or problem, give it a quick but thorough examination, and arrive at a prompt decision. He wastes none of his energy on vacillation; once having arrived at a decision, he can be trusted to waste none on changing his mind. Needless to say, he is a very popular executive.

During his long association with the A.S.M. there has been only one period when his energy failed him — and understandably. Early in the war years LT. WILLIAM HUNT EISENMAN, JR., piloting an ill-fated plane of the Air Transport Command, was killed. Overwhelmed by the abrupt end to the career of their only child, of whom they were so very proud, both Mr. and Mrs. Eisenman staggered through the next two years somehow. Mrs. Eisenman carried on with her full-time job as ordnance inspector; he took what comfort he could in his work — but work, however congenial, is no immediate palliative for personal loss.

Every biographical appreciation, I am told, should tell something about the hero's hobbies, but Bill Eisenman is absorbed in his work to the exclusion of extracurricular activities. When he was in college he played football, and in California he played on the Olympic Club, an early professional team of more than local fame. Now, however, his athletic interests center around 'rastling with a hay-baler and a farm tractor. Once a 90 to 100 golfer, he now spends his free time on a farm near Novelty, Ohio, and is poring over a model of a ranch house he is thinking about building in the California desert. These things provide rest from work rather than an active hobby.

Bill's only hobby is people — nor is even that hobby unrelated to his business, since it is probably the most important single factor in his business success. He didn't plan it that way — he just feels friendly. Kent Van Horn tells a typical story of how he first met Bill. A student at Yale, he happened to attend a New York Chapter meeting, where he felt as ill-at-ease as a kid would in the midst of a group of strangers, most of them looking like mature professional men. He was very much relieved when a round man with an earnest twinkle in his eye came up to offer his hand, and tell him his name was Eisenman. "He didn't even know my name, and neither he nor I remotely realized I'd be president of the Society in a few years." A casual acquaintance is as welcome a caller at his farm on a Sunday as his closest friend. He loves to be surrounded by company. He not only likes people — he admires their abilities. Every member of his organization, no matter on how modest a level, is a world-beater, in his opinion.

Bill's liking for people has made him maintain a personal touch in the A.S.M. in spite of the fact that the membership now numbers 20,000. Probably the majority of them have met Bill at least once. Accompanying the current president, he visits at least half of the 76 chapters each year. He really *visits* with them and gets their reactions on new projects and gathers up ideas for the Society's progress. Many is the ⊕ president who has been run ragged on the grand tour.

Such, members of the American Society for Metals, is the personality of your National Secretary. To many of you this account is a work of supererogation, for you know him and something of the history of the Society, and to you

The A.S.M. = WILLIAM HUNT EISENMAN = "Bill"

To those of you who do not know him yet, even by reputation, it can safely be said that when you meet him, you will like him, if for no other reason than that Bill will like you. ⊕

American Society for Metals

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THE GOLD MEDAL OF THE AMERICAN SOCIETY FOR METALS

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CHARLES H. HERTY, JR.	1931	ALFRED L. BOEGEHOLD	1938	MAXWELL GENSAMER	1945
EDGAR C. BAIN	1932	EDMUND S. DAVENPORT	1939	JAMES B. AUSTIN	1946

†Deceased

Steel in the Chicago District

Photo by Robert Yarnall Richie for Carnegie-Illinois Steel Corp.

Hot and Cold Strip Mills

Important Advances Made in the Chicago Area

By E. D. Martin*
Assistant Manager
Metallurgical & Inspection Dept.
Inland Steel Co., East Chicago, Ind.

Rolling of strip and sheet in continuous mills at a rate approaching a half-mile a minute and in continuous cold strip mills at nearly a mile a minute are achievements resulting from the efforts of dozens of engineers and organizers in as many different times and places. Notable in Chicago is Inland's very large, pioneering 76-in. mill, which in 1936 rolled the then record 860,000 tons. Notable also are the many advances made by Inland's metallurgists in cold mills and cold rolling that have improved the deep drawing qualities of the sheet and strip and the surface qualities so necessary for "paint jobs" and for successful use in tin-plate.

THE AUTOMOBILE DESIGNER probably dreamed 30 years ago of the smooth-flowing lines of the modern motor car, and the early refrigerator stylist was undoubtedly irked by the manufacturing limitations imposed by the steel he had to use. Not so many years ago a Ford automobile fender was a bent steel band, unsightly to behold, of a shape which made its function as a mud guard obvious. It was the development of steel of light enough gage, in sufficient width and with improved physical properties, that has permitted the deep drawing of the beautiful automobile turret tops and fenders, the sleek refrigerators, the attractive business machine housings that our designers and stylists could formerly only dream about.

This is the story of the contributions of the Inland Steel Co., at its Indiana Harbor Works, and others in the development of rolling methods which helped make such versatile steel available.

While steel was hammered and forged for early implements and the armor and weapons of medieval knights, cold and hot rolling of the soft metals is also a relatively old art. The earliest *record* is about the year 1495 in the form of a sketch by that great philosopher, artist, scientist and engineer, Leonardo da Vinci. In 1615 it is recorded that a hand-operated mill was built for the rolling of lead. This soft metal was reduced to sheet form for use as gutters on houses and other applications of that nature. No further developments were described until the year 1761, when there appeared a publication giving the principles of flat cold rolling. Exactly a century later the first patents were granted in Central Europe and England, and shortly thereafter (1864) in the United States. By this time we find that the art of cold rolling had progressed to such an extent that both waterpower and horsepower had supplanted handpower of human beings for turning the rolls.

While the earliest rolling operations were confined to soft, ductile metals such as lead and gold, we do know that there was a considerable amount of cold rolling as well as hot rolling being done on iron. For example, two inventors appeared in England (John Hanbury and John Payne), who both claimed the invention of a process of making sheet iron by rolling it between cast iron cylinders. These early products would doubtless now be

*The author desires to acknowledge cooperation of his associates, A. J. Castle, superintendent of cold strip and tin mills, and J. F. Mayberry, superintendent of hot strip mills of the Indiana Harbor Works.

classed as thin plate rather than as sheet or strip.

It is a known fact that from the Civil War to the end of the century there arose increased demands for flat rolled products to be made from steel, and that small mills were built at several places in the eastern states for rolling thin steel stays for women's corsets. Corset stays had created a demand for narrow widths — true "strip". From this time on, a succession of rolling mills was constructed. Into each one was built improvements until the cumulative effect of these ideas, trials, defeats and victories led to the giant and intricate high speed mills of today.

In this century, bursts of activity in constructing continuous hot strip mills and cold strip mills occurred in the late twenties and middle thirties. America entered the last war with a capacity to roll approximately 20 million tons of continuous strip steel annually. Much of this was readily converted into the manufacture of ship plate and was an absolutely essential factor in the success of our wartime shipbuilding program. Now, in the postwar period, with all mills reconverted for thin gages, we are witnessing another burst of activity to modernize existing mills and to construct new ones. Even before the war the steel industry had invested nearly 500 millions of dollars in these mills; now many more millions are being spent for badly needed new ones.

The past 30 years, coincidental with the life of the Chicago Chapter, ⊛, have been packed with the imaginative thinking, the painstaking and often disappointing experimentation, the pioneering construction and operation of continuous strip rolling mills that contributed so much to our great strides in industrial power. In this drama the Chicago area took a busy part and the Inland Steel Co. made a record of which it is proud.

It was in 1923 that a 58-in. continuous hot sheet★ mill was built at Ashland, Ky., after the design of John B. Tytus, who had been experimenting for ten years. While other unsuccessful and partly successful semicontinuous hot sheet mills had been built, it was this successful mill which pointed the way to continuous hot strip★ rolling in wide widths. By 1926, A. J. Townsend and H. M. Naugle had built a successful hot strip mill at Butler, Pa., which produced for the first time hot rolled steel strip 36 in. wide. (These two steelmen had considerable previous experience with a rolling mill at Massillon, Ohio, where they had rolled up to 24 in. wide down to 16 gage.)

A. J. Castle
Supt., Cold Strip and Tin Mills
Inland Steel Co.

Several other mills of this type followed with changing design until the construction of the very large 76-in. continuous hot strip mill of the Inland Steel Co. at Indiana Harbor, Ind. This mill started operation January 26, 1932, and was an outstanding success. Its principal design features became standards that were adhered to, as many such mills were built throughout the country.

Because of its success, this 76-in. mill is important historically. Many sweated hours of endeavor were expended to develop sound operation and maintenance. Examples of its achievements are as follows: It was the first continuous hot strip mill to produce wide sheets for the automotive field. It was on this mill that controlled finishing and cooling temperatures, application of water sprays, or holding on the hot bed, were used to control the grain structure. Grain size control made the steel responsive to subsequent cold reduction for the automotive industry's car roofs, front fenders, and quarter panels. Temperature recorders were installed at three stations to assist this control. These practices were developed early in 1933 on Ford front fenders calling for sheets 62x85 in.

★In this article "sheet" refers to thin material rolled or sheared into oblong areas; "strip" refers to thin material sometimes but not necessarily narrower than sheet but always of such length that it must be handled in coils. "Continuous sheet" refers to sheet that is rolled from large slabs like strip — that is, the hot metal is rolled through several stands of rolls in quick succession until reduced to final thickness. "Continuous sheet" is edge-trimmed, annealed, pickled and cold finished (and sometimes even shipped) by the coil. Ordinarily the shearing into short lengths is one of the last finishing operations on continuous sheet. Prior to the invention of the continuous sheet mill, sheet was rolled from small bars either singly or in doubles on hand-fed mills.

There were other "firsts" on this mill. It was the first such mill equipped to cross roll. On its No. 9 stand the first high pressure oil bearings on a 4-high mill were successfully used. This mill could roll strip 72 in. wide, which was closer to rated width (76 in.) than had yet been attained. Many detailed changes occurred on this mill representing developments in roll materials and roll design. By 1936, orders became more plentiful as we rose from the depth of the Great Depression. This gave the mill a chance to show what it could do. In that year 860,000 tons were rolled, leading the world in tonnage produced on a continuous mill.

On July 26, 1938, the Inland Steel Co. put into operation at Indiana Harbor a 44-in. continuous hot strip mill which incorporated many advances in design. This mill rolled at high speed (2140 ft. per min.), down to 18 gage. It had a very long run-out table — 377 ft. from the last roll stand to the coiler — to give enough time to condition the steel, even when it was passing at such a high rate. This was the first mill to dip the hot coils into water to change the character of the scale and so to secure more rapid attack by the acid pickle, and other advantages. This 44-in. mill could roll strip down to 18 gage in any width from 8⅞ to 42 in.

J. F. Mayberry
Supt., Hot Strip Mills
Inland Steel Co.

Cold Rolling and Tin-Plate

Each of these continuous hot strip mills advanced the art of rolling hot steel. Equally valuable advances were made by Inland at Indiana Harbor in the cold rolling of steel and in the commercial manufacture of tin-plate solely from cold reduced steel.

Prior to the early 1920's, the cold rolling of steel strip was a specialty involving low tonnage and was confined to certain mills rolling narrow strip. Tin-plate — a far more important item, from the standpoint of tonnage — was also rolled on hand mills by specialists up to the late 1920's and involved much back-breaking labor. When, in 1931 during the Great Depression, the Inland management had the courage to plan an expansion into the cold rolling and tin-plate fields, we had no hand mills. The can manufacturing industry, through the course of years, had become highly mechanized and the quality requirements for the raw material — hot dipped tin-plate — were becoming more rigorous. It was a question whether they could be met by steel that had been hot rolled on a continuous mill and then cold reduced — also in continuous mills — to proper gage and temper before being sheared into the relatively small pieces of "black plate" required for the coating operation (hot dip tinning).

Under the immediate operating direction of A. J. Castle, while in charge of the continuous cold reduction mill at Yorkville, Pa., strip steel was reduced to tin-plate gages for the first time. Important in attaining this result was the use of a cold rolling lubricant. It was there that Castle introduced the use of palm oil for this purpose. It was soon discovered that a proper surface for tinning required that the strip, cold reduced with the aid of a lubricant, had to be washed to secure a clean metal surface before annealing. While cold reduced strip was successful for tin-plate of some grades, other grades had to be made from sheets hot rolled in the old manner on hand mills.

Nevertheless, Inland decided to go into the manufacture of tin-plate made entirely from cold reduced sheets. For the above-mentioned reasons, the steel industry considered this pioneering effort to be a definite gamble, and it was carefully watched by other producers. Inland Steel Co. had been fortunate in obtaining A. J. Castle as superintendent of its new cold mill. The background of experience which he had acquired was of great value in the venture of producing tin-plate, to which the company now committed itself.

Other important changes in the art of continuous cold rolling came from the competition in the automotive industry that was resulting in more curved lines and rounded shapes in automobiles. Pressure rapidly developed on steel mills for better and better drawing quality in the steel sheet and wide strip to permit this greater beauty of design. Although normalized hot rolled sheets

were meeting this demand, cold rolling could produce metal of equal quality at lower cost, and certain mills installed units for this purpose. Therefore, in 1931 Inland Steel Co. started the construction of a new 54-in. cold rolling mill (later widened to 72 in. in 1932, thus becoming by far the widest mill of its kind at that time).

It was during this period that there was developed at the Indiana Harbor plant a new process for rolling these wide sheets which tremendously improved their drawing properties and imparted a new and beneficial surface. It simultaneously eliminated many of the troubles which had been encountered in manufacture, and permitted even greater streamlining of automobiles.

E. D. Martin
(The Author)

This process consisted in sandblasting — or, as was developed a few months later, shotblasting — of rolls so they would imprint a dull surface on the sheets squeezed between them. This surface permitted higher annealing temperatures (thus obtaining more desirable physical properties of the steel) without sticking of the surfaces to one another at any unduly high spot. It also provided a better holding power for the lubricants applied to the surface in subsequent drawing operations, and this resulted in better drawing characteristics. The process was covered by two patents (U.S. 2,105,968 and 9) which have been known as the "Castle patents". This was a definite advance and was generally adopted by other producers.

Prior attempts had been made to dull the surfaces of rolls by passing between them hot rolled sheets with heavy scale, or by acid pickling of the roll surfaces. The Castle dull rolls imprinted on the steel a surface pattern of different character which was more successful in attaining the desired results.

When, in 1933, Inland placed in operation its newly constructed cold rolling facilities for the manufacture of tin-plate, it was the Castle dull roll which contributed greatly to the successful manufacture of all grades of tin-plate from cold reduced steel. While tin-plate produced from steel hot rolled on the old hand mills had a grain structure which permitted the forming of smooth cylindrical can bodies without fluting, cold reduced steel, after annealing the work hardened material to make it soft enough to manufacture into cans, tended to "flute" or "panel" badly.

Inland tin-plate provided a cure for this in the form of a light skin pass or temper pass with a Castle dull roll to roughen the surface, followed by a pass through smooth-surfaced rolls to flatten the minute projections of the surface. This cold worked each surface of the strip so that an effect similar to 3-ply wood veneer was obtained. The successful manufacturing process started with hot rolled strip steel, pickled in sulphuric acid in continuous lines. This pickled strip was then cold reduced in strip form between dull rolls, washed free of lubricant, box annealed in coils and given skin or temper passes. Such strip, either cut and put through tin pots in the conventional hot-dip process, or coated with electrolytic tin in a continuous manner before shearing, did not flute and could be processed into a high quality tin-plate. The steel industry rapidly adopted this new method of making the steel for hot-dip tin-plate, and the practice is almost universal in our country today.

This was another triumph of Inland Steel Co. and metallurgists in the Chicago area, which helped to pack this region's history of the past 30 years with accomplishments in a basic industry that have been of great value to our country and its citizens.

A Deep Draw in Cold Reduced Sheet

Production of High-Strength Steels With Improved Machining Characteristics

By F. O. Johnson
Chief Chemist
Wisconsin Steel Works
South Chicago, Ill.

Too frequently the metallurgist, in his enthusiasm to produce a metallic combination with perfected strength, toughness, noncorrodibility, or creep strength, neglects the fact that his brethren in the fabricating shops must shape, cut, join and otherwise manipulate the alloy. The cost of machine shop operations, in fact, often makes or breaks a perfectionist's dream. Mr. Johnson, in this story of developments in a Chicago industry, tells how machinability of certain important openhearth steels is improved to a gratifying degree without any detectable loss in the usual physical test results.

In any review of advancements in the steel producing industry since World War I, one continuing stream of events is obvious — the production of analyses, shapes, finishes and other qualities designed to make the steel fit the job better than ever or to fit jobs that were new and unique. This ranges through the whole family of steels, from the soft steel sheet★ through the medium alloy steel of deep hardenability, to the steel highly alloyed for special chemical resistance or heat resistance.

Steel, the iron-carbon alloy, can thus be modified to fit into innumerable applications. In nearly all of them the bar, forging or casting passes through the machine shop and more or less work is done on it there. Frequently machining costs more than the raw material — sometimes more than all other operations combined. It is not strange, therefore, that much attention has also been given in the last 30 years to the problem of improving the machinability of steel. Perhaps it is more strange that so little, comparatively, has been accomplished in this direction.

Early in the development of the steel industry as we know it today — 80 or 90 years ago — it was known that more than a few hundredths of a per cent of sulphur made "hot-short" steel that was very difficult to roll. For generations this element was something that had to be avoided — its damaging influence could only partly be counteracted by an increased amount of manganese. Much later it was found that the *addition* of small amounts of sulphur had a profound effect in improving its machinability.† Thus it was necessary for the steelmaker and user to balance the bad against the good, and as a consequence these resulphurized steels could be used only in applications in which high strength was secondary to good machining characteristics.

For the 30 years of the ⊕'s life, resulphurized bessemer steel has held No. 1 position in free-machining characteristics. It still holds this posi-

★Editor's Footnotes — An interesting description of the improved steel sheets is given by E. D. Martin on page 561.

†It would be interesting to know who discovered this and when. The Editor carefully studied the metallurgical literature in 1920 and presented the results in a paper before the New York Chapter (*Journal*, American Steel Treaters Society, V. 2, 1919-1920, p. 368). This article made no mention of machining characteristics.

tion today in spite of many attempts within the last 15 years to produce a resulphurized open-hearth steel with comparable properties. The application of this steel also was limited to that field in which high physical properties were secondary to machinability.

Nevertheless there is a vast field of applications in which steel is called upon to develop high physical and mechanical properties as a major requirement. It is in this very field that the greatest machining difficulties are encountered. That such a circumstance might be expected is apparent when it is considered that the forces which act in the various machining operations are *destructive* forces. Thus it would seem that in order to have good machining properties the steel would necessarily offer little resistance to the destructive forces which come into play in machining. The reverse would also appear to be true; that is, a steel that possesses the high physical strength and toughness necessary for exacting engineering applications would offer great resistance to destructive forces and therefore would be difficult to machine.

The present-day metallurgist also knows that microstructure also plays an important part; some structures are much more favorable than others from the standpoint of ease of machining. Generally, where the application requires a finished part of high physical strength yet light in weight, an intermediate heat treatment is necessary to create a structure which offers less resistance to machining operations; after machining, the part is given another heat treatment to develop the ultimate physical properties. But here many expensive difficulties often arise such as warping, growing or shrinking, or surface changes.

Another factor which enters into the machining problem is the cleanliness of the steel, particularly as regards those abrasive inclusions which have a very harmful effect upon the cutting tools.

While sulphur had been put into low-carbon steel for years to enhance its machinability where this was of paramount importance, it was not until just prior to the last decade that an attempt was made to use it in higher carbon steels of the heat treatable class. This class of steels was known in the S.A.E. list as the X1300 series. In these steels the manganese content was increased considerably over normal in order to overcome the effect of sulphur on the physical properties. (For example, in S.A.E. X1335 the carbon is 0.32 to 0.39, manganese 1.35 to 1.65, and sulphur 0.08 to 0.13.) Also, the plain carbon and ordinary low-alloy steels were made with small amounts of sulphur added, and these steels met with some degree of success in a few of the less critical applications. In the list of standard stainless steels we also find three types with 0.07% min. sulphur for enhanced machinability.

Until recently most of the relief from machining troubles encountered with these intermediate and higher carbon steels (or "heat treatable steels" as they are sometimes called) came from improve-

Co-Inventors of Sulphite-Treated Steel

The Author
F. O. Johnson

L. G. Graper
Supt., Testing & Research Dept.

E. L. Ramsey
Supt. of Steel Production
(Retired)

ments in machine design, better cutting tools and improved cutting fluids. However, these changes in the machine shop, successful though they were, did not remove the desirability for treating steel in some manner in the mill, during its production, to enhance its machining characteristics when in the heat treated condition, and a method that would have no effect on its physical properties.

Sodium Sulphite as an Addition

In the course of experimental work along this line prior to World War II, other elements besides sulphur (such as lead and selenium) were proposed and used to a certain extent. Likewise mill processing was scrutinized and various combinations of cold work and heat treatment were found to be valuable aids to machinability. Confining our attention to sulphur, however, it should be noted that small amounts can be added in the form of molybdenum sulphide, and machining characteristics are improved to a very encouraging extent. Such a scheme, however, must be confined to the alloy types that normally contain molybdenum — or some compensation made for this element added with the sulphur.

Extensive work along this line, which of course must be done on a large scale and checked by carefully planned production in the machine shop, was hampered during the war by the desire to concentrate steel production in as few types as possible, and a variety of other causes that need not be enumerated. Nevertheless the need for savings in the machine shop through improved machinability was more urgent than ever. It was fortunate that prior to 1942 the Wisconsin Steel Works in South Chicago had made over 6000 tons of steel to which the necessary sulphur was added in the form of sodium sulphite (Na_2SO_3) during tapping from the openhearth furnace.* It was found that no compensations need be made for this treatment and it is practically unlimited in its application to alloy and carbon steel alike. Steels properly treated with sodium sulphite can be processed in the same manner as the untreated steel without suffering any significant adverse effects. They will respond to heat treatment equally as well. The effects are most notable in steels containing over 0.30% carbon — or, generally, the heat treatable types.

While sulphite treatment does not produce a so-called "free-machining steel", and it is not claimed to be a panacea for overcoming all of the difficulties encountered in machining, the applications to various important machine parts prove it to be very effective in improving finish, speeding up machining operations, and increasing tool life.

This treatment consists essentially of adding sufficient sodium sulphite to the steel as it is tapped into the ladle to increase the normal sulphur content by about 0.020 to 0.025%, but maintaining the total sulphur content within the range of 0.040 to 0.060%. In this manner a sufficient amount of sulphides is distributed throughout the steel to improve the finishing quality. At the same time the sodium oxide which results from the decomposition of sodium sulphite at elevated temperatures reacts with the acid oxides (silica and alumina) to form fluid slag which rises to the surface; thus the abrasive inclusions are fluxed out of the steel. With the abrasive inclusions reduced to a minimum, the machine tools used on the sulphite-treated steel hold their cutting edges for considerably longer periods.

Comparative data obtained when sulphite-treated steel was substituted in regular production setups often show a surprisingly great increase in tool life. Usually, finish was greatly improved. In no case was it found that this treatment produced any adverse effects in machining.

A study of deviations in physical properties of sulphite-treated steel from those of untreated steel indicates no consistent, significant deviation to exist, except in the impact values in transverse section. In all other physical properties tested the deviations were both positive and negative, indicating that any effect is less than those produced by other variables and therefore cannot be detected by regular testing procedures. Deviations of the impact values of the transverse specimens were all negative except in one case. When it is considered that impact values of the control specimens were also very low, these differences are relatively unimportant except in applications where the part is subject to high impact stresses in a plane parallel to the grain flow.

Sulphite-treated steel, then, is a steel that is applicable to a wide field of uses as a means for obtaining improved machining practices. As stated above it is not a panacea for overcoming all machining ills, but it will go a long way in alleviating them. It is only one more instance of where metallurgists and engineers in industry, in the Chicago region and in the lifetime of the, have advanced along lines of great importance to industry through all the United States. Progress will continue to be made in improving all of the desirable characteristics of steel and the ultimate will not be reached until it is perfected to the point where the steel will be able to resist the irresistible force and yet will cut like butter!

*See "Observations in the Making and Use of Sulphite-Treated Steels", by E. L. Ramsey and L. G. Graper, *Metals Technology*, April 1942.

Toolsteel Progress During 30 Years

By Arthur T. Clarage
President, Columbia Tool Steel Co.
Chicago Heights, Ill.

It is proper to say that the toolsteel industry is the cradle of modern metallurgy. "Quality" was insisted upon even in the days when each bar-end was fractured and graded. The first alloy steels came from the crucible. The toolmaker was the first hardener and his forge the first controlled atmosphere furnace. Grain size control and depth of quench hardening were toolsteel innovations. This story of a toolsteel mill in the Chicago district shows how the venerable industry modernizes its equipment and its viewpoint, in pace with the requirements of its progressive customers.

WHEN THE American Society for Metals, then the American Steel Treaters Society, was formed in 1917 in Chicago, and the Columbia Tool Steel Co. became one of the first "Patron Members", few if any realized that we were face to face with one of those situations that can be described as a great need creating great opportunity. Looking backward, it is easily seen that the ⊕ and its predecessor societies were destined to play a large part in bringing together men engaged in production and use of toolsteel. Beyond this, the ⊕ has been a highly important factor in promoting connections between men with aptitude and interest, the toolsteel producers, and the toolsteel users. This evolution, which has been very much for the common good, is too frequently taken for granted and too little credit given where credit is due. Much has been accomplished but more important than the accomplishment to date is what this points to in the future.

It is with thoughts of the future that this review of the past is offered in order to refresh memories and stimulate new interest.

Toolsteel of 1917 included much that we do not think of as "toolsteel" today. This class of material consisted of a small proportion of high speed steel, almost no oil hardening die steels, a large portion of carbon toolsteels — some with, but mostly without, small alloy additions. In the carbon toolsteels, a wide range of carbon content was offered in order to supply needs from simple blacksmith's tools to surgical instruments.

A large part of the ultimate usage was then for hand tools. Some hot work alloy toolsteels had appeared and these were more important at the time than the alloy die steels.

"Cherry red hardening" was the order of the day.

Modern Industry — The story of mass production, the development of modern machine tools, and the raising of the physical properties of toolsteel is like the old question of "Which came first, the chicken or the egg?" Before World War I, the automobile industry opened the door for the modern machine tool and for modern toolsteels — but whether the need led the way, or whether machine tools made the way possible, or whether the "better" small pieces of toolsteel somewhere in the machine made it *all* possible, will never be known for sure.

However this may be, there can be no doubt but that opportunity had arrived. The history of the toolsteel business clearly shows that this opportunity was met.

Thirty years ago, when ⊕ took root, we were in the middle of World War I. Quantity of reasonable uniformity, rather than quality in fine detail, was the order of the day. The glamour products of that period consisted of guns large in caliber, but sadly lacking the fine controls for

pl‹cing, loading and aiming; tanks with the terrific speed of 15 miles an hour; the automobile — four-cylinder — with wood wheels and wood body frames — complete with acetylene lights and windshield for a few dollars extra. Radio was referred to as "wireless", and its use was very limited. The aircraft had just outgrown a structure made of bamboo poles. The products of this period and the production of them depended on a few steels whose properties were controlled mainly by changes in carbon content.

In contrast, today's great quantities of precision-made, interchangeable mechanical parts were not heard of. The astronomical numbers of automotive parts, household devices (including refrigerators, stoves, cooking utensils, laundry machines, vacuum cleaners, sewing machines, lawn mowers, and household hardware), the farm machinery, the inexpensive watches, clocks, mechanical pencils and pens, had not been dreamed of in 1917. The myriads of electric motors and bearings and gaskets and fitted mechanical parts were still for the future. Business machines were in their infancy.

In the background of this great industrial evolution was toolsteel, and it was necessary that toolsteel meet the challenge of these new developments. It did just that!

Pyrometry and Other Controls — At the inception of the American Steel Treaters Society in 1917, the devices available for testing and measurement were very limited. The blacksmith (who was also the toolsteel hardener) used his file to test the hardness of hardened tools. Scleroscope hardness testers were a rarity. Pyrometers were a curiosity. Any steel treater of that day was convinced he could read furnace temperatures better by eye — even after a "lost week end". He supplemented this skill by such visual observations as to the way it "sweat" or "flashed". One highly regarded tool hardener, known to many of the original group of "Steel Treaters", gaged the tempering temperature by the way his spit bounced off the piece as it came from the tempering forge.

Toolsteel producers were quick to take up pyrometry. It was first used, in my own company, in the annealing furnaces where it was soon discovered that prior practice was highly variable. With pyrometers and hardness testing instruments in use, attention was focused on other standardization. The automobile industry had commenced to make interchangeable parts and used the word "tolerance" and we took up the idea. Analysis specification limits with minimums and maximums came into being after World War I. This was followed by thermal tolerances in melting, casting, forging, and rolling. Size tolerances then came into being and, lastly, hardenability.

It was in this stimulating atmosphere that toolsteel production in the Midwest grew up.

Three of the Men Responsible for Progress at Columbia Tool Steel Co.

R. M. Sandberg
General Manager

Arthur T. Clarage
President*

Adam M. Steever
General Superintendent

*Taken in 1931, when he was National Treasurer.

As industry expanded, and the "demands" on tools increased, the tool and die industry needed sounder and cleaner steels; steels that would machine easily; compositions that could be hardened with dimensional accuracy; "oil-hardening steels" and steel that would not grain-coarsen on hardening. In order that the steelmaker could meet these needs, many changes in steel mill production practice as well as chemical composition were necessary.

Changes in Practice — In 1917, crucible melting was generally used in the manufacture of toolsteel. While this was a good medium for melting, it was a high cost operation and it did not control phosphorus, sulphur or residual alloys. The electric furnace operation brought with it considerable difference of opinion as to what constituted proper deoxidation practice. The use of aluminum as a grain size inhibitor was recognized at an early date, and much mystery surrounded its use. The head melter wrapped the aluminum in tissue paper so that no one knew what or how much was being added to the melt.

During the 1920-1930 decade, largely due to the interest in this subject stimulated by the American Society for Steel Treating, a considerable amount of light was shed on the subject, which resulted in an improved deoxidation practice and grain size controlled steels of all types and for everyone's benefit. This is only one of a number of achievements of the last 30 years where the free interchange of ideas has immeasurably speeded the widespread adoption of progressive measures. It would be hard to pick out the exact origin of many of these ideas. They are talked about; other men try them; good results may alternate with failures; the "bugs" are worked out; soon the new routine becomes practically standard practice. This interchange of ideas by the men concerned is the characteristic feature of American industry in the 20th century. As long as publicity and discussion are fostered by such groups as the ⊕'s chapters, there is small danger of a stagnating mechanical industry.

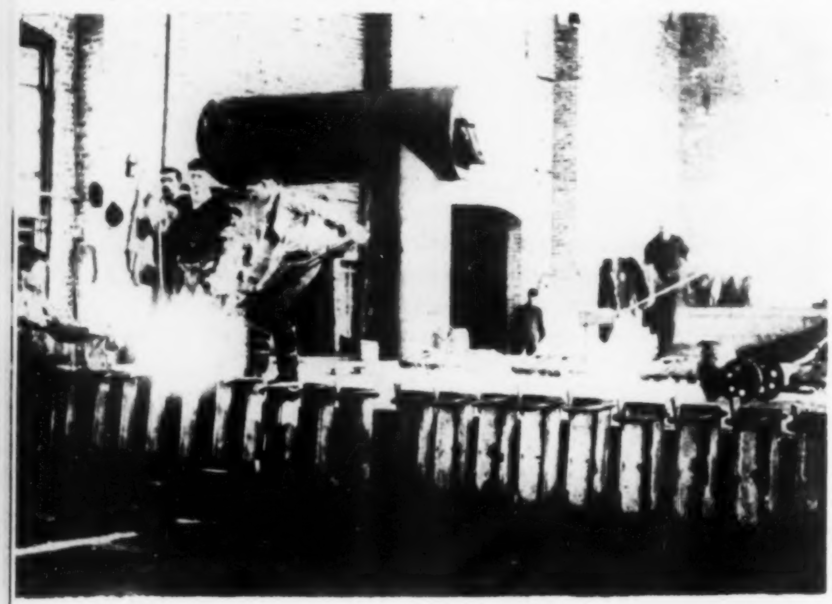
Electric Annealing — Up to about 1921, annealing was primarily a softening operation. Little attention was paid to the structure resulting from the annealing practice. In 1923, Columbia Tool Steel Co. installed and put in operation the first automatically-controlled electric annealing furnaces to be used for the annealing of toolsteel bars. A controlled heating, holding and cooling cycle was used to spheroidize the annealed structure. This was a definite step in improving both machinability and hardenability.

Hot Etch — The development of the hot etch test afforded an easy (if not too reliable) method of inspecting toolsteel structures. One prime result was a considerable study of mold design and casting temperatures. In regard to mold design, probably the most important step was the use of the big-end-up mold with extreme tapers and generous refractory hot tops or sink heads. In addition to this, a great many experiments were made to determine the relation between mold wall thickness and ingot cross section. As the demand for increased soundness and reduced center segregation became more imperative, the use of the tapered ingot afforded a means of appreciable improvement in this direction. As a result of these studies, by 1929 we had developed molds of our own design embracing those features that appeared to contribute most to soundness of the product.

Melting Control — Parallel with this effort, the effect of casting temperatures was carefully investigated. While some work in this direction had been done with crucible practice, full benefit of casting temperature control was obtained on changing to the electric melting furnace in 1929. By 1936, temperature control was used on all heats and pouring limits for all types of toolsteels were established. The importance of temperature control is indicated by the fact that it is necessary to pour a given toolsteel composition within a 50° F. temperature range to obtain the maximum in soundness and structure.

In 1929, Columbia Tool Steel Co. installed the first electric melting furnace having four-

Toolsteel Melting — 1917
Pouring a Crucible; 100 Lb. of White Hot Metal Into the Mold



voltage control. By means of this wide range of arc voltages, quickly obtainable at the control board, the flexibility of toolsteel melting practice was appreciably enhanced. Another step forward in melting practice was made in 1940 when the first top-charge electric furnace was installed for toolsteel melting.

Automatic control of forging furnaces was pioneered by our firm in 1935. Gas-fired furnaces for heating toolsteel ingots and billets for forging and rolling were designed with both atmosphere control and temperature control. This installation enabled us to control decarburization in heating, and gave a highly desirable degree of temperature uniformity, which was impossible with other heating units available up to that time.

Other means of product control that have been adopted during the last decade are magnaflux inspection for surface defects and Jominy testing of all carbon and low-alloy heats for hardenability.

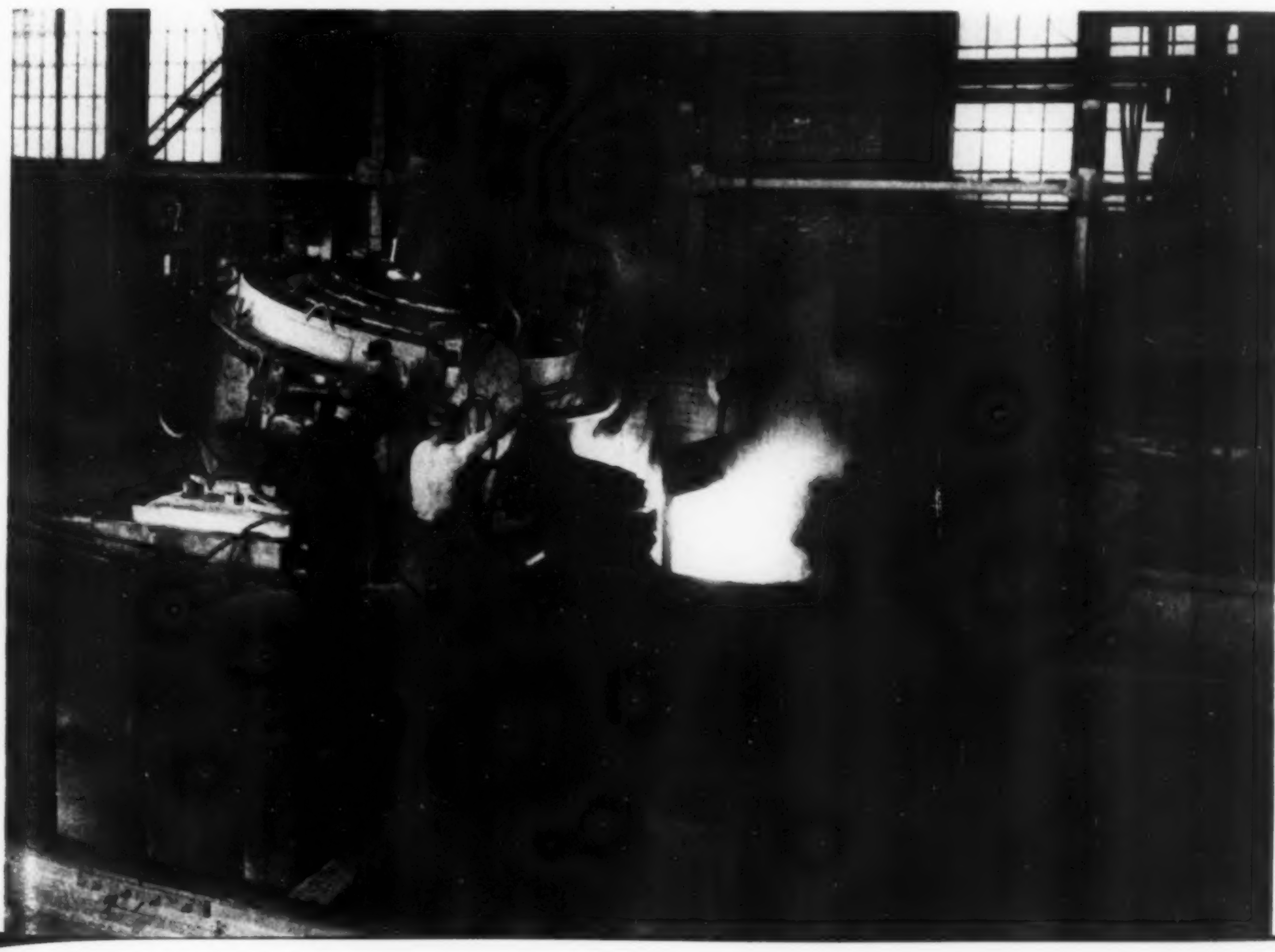
Composition Changes — As the requirements of industry increased, the number of toolsteel types to meet these demands increased. In addition, a large number of compositions were changed by an increase in alloy content. In our opinion, the most outstanding compositions adopted by the tool and die industry in the last decade are the high-carbon, high-chromium die steels. Columbia Tool Steel Co. offered its first steel of this type in 1926. At that time users found high-carbon, high-chromium steel "too expensive" and "hard to machine", and were much concerned over the "stringy" structures in the early types.

It took almost 20 years for tool and die users to appreciate the production possibilities of these steels, but in the last decade their use has been at a steadily increasing rate until, from a value standpoint, they are now second only to high speed steels. In view of their enviable performance record, we are led to expect that an even larger proportion of cold work tools and dies will be made from this material. We believe that unless some radical new principle of alloying is discovered, the high-carbon, high-chromium steels are going to continue to be the high production die steels.

Conclusion — No effort has been spared to make toolsteels capable of present-day performances. It is impossible to say how much these performances are due to toolsteel alone.

If the present is any guide as to the future, we can see the development from here on. It will be one of increased measure of well informed attention to the variables in production of toolsteel which affect ultimate performance. This should lead to the increased use of higher and higher physical properties. All of this will require greater employment of well informed talent and, again, if the past is any guide, this will pay out well in higher performance and over-all economy — as it has in the past 30 years.

Toolsteel Melting — 1947: Pouring an Electric Furnace; 6 Tons Into the Ladle



30 Years' Advance in the Basic Openhearth

By J. J. Golden and M. F. Yarotsky*
Division Superintendents of Steel Production
Gary Works and South Works, respectively
Carnegie-Illinois Steel Corp.

One might ask himself, "What is there new in openhearth steelmaking? The furnace, the regenerative checkerwork, the melting and refining methods — all have been known since 1864." Since it has been the dominant process in the U.S. since 1909 (due at the time to the operation of the new plant at Gary, the world's largest, which had no Bessemer converters at all), it would be remarkable indeed if the furnace, its auxiliaries and the operating technique had not been so refined in every detail that a Rip Van Winkle — a bearded melter emerging from a 30-year sleep behind a sand dune — would never recognize the old shop.

MANY radical changes have taken place in the manufacture of basic openhearth steel during the ●'s lifetime. Furnaces have been changed in size and design, refractories have been improved, fuel consumption has been greatly reduced, operating techniques have been improved, tapping and teeming have been brought under better control — all from the application of technical knowledge. Great advances in safety practices have also been achieved, the steel industry now being one of the safest in which to work.

Where formerly steelmaking was an art governed by rule-of-thumb and personal knowledge gained only by experience, today we find it more nearly a science. This has been accomplished by the cooperative efforts of the openhearth operators, metallurgists and fuel engineers, whose work has been closely coordinated with over-all plant problems. Science has come into its own and has well justified its application to steel production by operators trained to rely on metallurgical, mechanical and chemical knowledge.

These advances have been nation-wide — nay, world-wide. A commendable open-door policy has spread news about an improvement in this, that or the other plant; soon everyone interested knows the facts. This interchange of information has been expedited by the existence of such organizations as the American Society for Metals, the American Institute of Mining & Metallurgical Engineers, the Association of Iron & Steel Engineers, and the American Iron & Steel Institute. The fraternity of steelmakers is such that it is frequently hard to pin the origin of any idea or improvement on any one man or organization. However, in what follows we have endeavored to limit ourselves to those technical developments wherein the men of the Chicago District have pioneered and have pushed to commercial utilization.

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*In any comprehensive general review much dependence must be put on willing associates. The writers, therefore, express their appreciation to the metallurgical departments and the operating departments at South Works and Gary Works for cooperation, particularly to C. J. Hunter, chief metallurgist at Gary Works, E. W. Pierce, chief metallurgist at South Works, M. J. Devaney, formerly assistant to manager of operation, Chicago District, and A. W. Robinson, ceramic research associate, Research and Development Division, as well as to men at the research laboratory of U. S. Steel Corp. at Kearny, N. J.

All through the 1920's producer gas was the only fuel available in the Chicago District. Steelmakers were seriously handicapped by the low calorific value of the coal most readily available. Sulphur was also a serious problem. Furnaces in 1918 were relatively small; the stationary furnaces tapped from 70 to 120 net tons per heat; the six tilting furnaces in the Chicago District were tapping 145. The big problem was how to get enough fuel and air into the furnace to make steel without doing undue damage to the outgoing end of the furnace.

Major developments in furnace design occurred during this first decade which were destined to affect the entire industry. Thus, pan bottoms were installed at Gary Works to replace concrete hearth foundations as early as 1921. The venturi port, developed at South Works, was first installed in 1920. This design not only provided "sharper working" furnaces fired with producer gas, but also was successful when oil fuel came into use. The use of basic brick was extended to provide vital locations in the furnace with prolonged life. Water-cooled straight-line reversing valves began to replace several types of antiquated reversing valves in 1921. Ribbed roofs, which were pioneered at South Works as early as 1910, by 1924 had been increased in thickness from 12 in. to 18 in., the ribs being 22½ in. deep.

It is today hard to remember an openhearth furnace without a sloping back-wall, yet the first one ever used was installed at South Works in June 1924. This invention practically eliminated the frequent back-wall repairs formerly needed, and greatly simplified bottom maintenance, as well as improving the working conditions at the tapping side.

As techniques and materials of construction improved, average furnace size continued to increase, so that in the early 1930's heats of 150 to 190 net tons became common. By 1941, United States Steel had developed a standard design for a 225-ton stationary openhearth furnace (double the average capacity of 25 years before) and it embodies the very latest developments in design, automatic operation, and instrumentation.

Refractories — Relatively recent improvements in basic refractory brick extended their use and by 1940 basic fronts and ends were being built. This gradual evolution has led to the recent construction of an experimental 120-ton all-basic furnace at South Works. This is strictly an experimental unit and is being operated on a commercial basis under all possible conditions, including the use of oxygen as a combustion aid. In addition to the all-basic roof and hearth, front-walls and back-walls, basic brick are installed in the side-walls, downtakes, and in the construction of the slag pockets up to the bridge wall between the slag pocket and the checker chamber.

Ladle of 100 Tons Molten Pig Being Poured Into Openhearth at Gary

During the past 10 years the Chicago District plants of Carnegie-Illinois have conducted intensive experimentation with magnesite and chromium ramming mixes for the construction of openhearth subhearths. The use of a sized, finer grade of magnesite instead of the coarser grain has speeded up the installation of bottoms, requiring less slag, and sintering-in faster. In May 1945, a new bottom was installed at one of the Gary furnaces, using 11 in. of sized magnesite with 10% of clean, basic slag, sintered over a subhearth of rammed chromium-base plastic material. Because of the finely sized particles of magnesite, the sintering was completed in a little over 100 hr. During the first eight months of operation, bottom delays on this furnace were practically eliminated, amounting to an average of only 8.9 min. per heat.

Instrumentation — The furnace of 30 years ago had practically no instruments for measuring the flow of fuel or for indicating temperatures or pressures. Nor were there many technically trained men available to install and service them, and apply the observations. The efficiency of combustion and the operation of a furnace depended entirely upon the operators' experience. The "metallurgical observer" was still unknown. We believe that the first indicating instrument used in connection with operations was a steam pressure gage at the gas producers. Around 1920 draft gages were installed in the flue system, and these were closely followed by recording flowmeters as coke-oven gas began to come into use.

The increased usage of tar and fuel oil in the late 1930's necessitated an accurate measure of their consumption, and consequently a liquid fuel flowmeter became standard equipment. Automatic furnace pressure controls were first installed in 1931, and pyrometers for recording temperatures of checkers and waste gases appeared in 1932. With the installation of automatic fuel-air ratio controllers and automatic mechanisms for reversing the gas flow, perfected within the last few years, mechanization of the openhearth temperature cycle is rapidly nearing completion, and a large number of furnaces throughout the steel industry are now so equipped.

Floor Laboratory in Gary Openhearth Shop No. 3

A complete list of the instruments and controls with which a large number of modern furnaces are equipped follows:

1. Recording gage for atomizing steam pressure.
2. Recording flowmeter for coke-oven gas.
3. Recording flowmeter for liquid fuel.
4. Recording pressure gage with automatic furnace pressure control.
5. Recording draft gage.
6. Recording pyrometers for checker temperatures, waste heat boiler, and stack temperatures.
7. Fuel-air ratio indicator.
8. Roof temperature indicator, with automatic roof temperature control.
9. Forced air control.

Since close control of combustion has followed improved furnace design, insulation and utilization of instrumentation, fuel consumption has decreased from upward of 6,000,000 B.t.u. per net ton (30 years ago) to the present level of about 3,250,000. Such decreased fuel has been accompanied by a proportional decrease in the refractory consumption.

The openhearth furnace of 30 years ago was entirely devoid of any type of insulating material, but the benefits to be derived were recognized in the middle 1920's. Since then the entire flue system, including port-end walls, side-walls, and arches; the checker chamber roofs, floors, bulkheads and side-walls; the slag pocket side-walls, floors and bulkheads — all these are insulated. The main roof is the only part of the furnace that is not generally insulated. (Some insulated roofs were tried about 10 years ago but the results were not promising, as roof life was considerably below normal.)

Automatic control of roof temperature was instituted about 1935, and many furnaces are now equipped with this device. A radiation-type pyrometer is sighted at a point near the middle of the roof; it registers temperature on an indicator at the control panel, which is in turn connected with the fuel controls. When the roof temperature reaches a critical point, the fuel input is automatically reduced until the temperature drops to a safe level.

Considerable thought was also given by the steel industry throughout the world to the problem of measuring the actual temperature of the openhearth bath. Our early experiments consisted of optical pyrometer readings taken directly on the metal through a suitable tube; a small flow of compressed air kept slag and metal out of the tube's open end inserted in the bath. Automatic recording devices were used in 1937 and 1938. Further refinements, resulting from cooperative studies with the Kearny research laboratory of U. S. Steel Corp., have resulted in the bath pyrometer in use today, with much experimental work still being conducted.

Among other techniques and instruments used to improve combustion efficiency are the current studies of flame radiation intensities and the analysis of waste gases by electronic devices.

Oxygen — Recently entirely new vistas in openhearth operation have opened through the use of oxygen for enriching combustion air or for rapidly reducing the carbon content of the bath. A considerable amount of experimental work has already been completed in the Carnegie-Illinois plants — as well as throughout the American and Canadian industry generally — and both methods of application are shown to be feasible, and can provide a reduction in the normal charge-to-tap time, as well as an appreciable saving in total fuel. Much work is yet to be done to evaluate the effect of oxygen on refractory life, and this is now being carefully studied on the all-basic openhearth furnace at South Works, as well as in other plants in the steel industry.

When large volumes of cheap oxygen become generally available, it is probable that the oxygen technique will become a standard part of the steelmaking process. As pointed out by the editor of *Metal Progress* in his "Critical Points" in the July issue, extensive application of oxygen, with its attendant speedup, will depend upon the development of improved methods of handling raw materials and product.

Metallurgical progress in the basic process has been slow and tedious because it is so difficult to make accurate studies of such high temperature reactions. Within the past 30 years, however, cooperative research between individual companies in the steel industry, the universities, and private research laboratories, has produced a mass of knowledge which the industry has put to profitable use. This has been utilized mostly through various "observer" organizations which made their first appearance in the early 1920's. These groups, which were later incorporated into "metallurgical process control units", have been able to observe the results of likely-looking ideas as they have been tried. The over-all result has been a definite gain in steel quality and production.

Some of the more important improvements made in the metallurgical control of openhearth steel production during the last 30 years are:

1. Correlation of the visual appearance of a slag pancake with its chemical composition (basicity and FeO content). This has provided a reliable guide for controlling phosphorus and for making ore additions. Slag control has recently been further developed by correlating basicity with the measured pH of a crushed slag-and-water mixture. Spectrographic methods for slag basicity are also coming into use, and appear to be quite promising. (Slag control was pioneered in the Chicago District in the late 1920's and investigations are still continuing. As a result of the work, slag volume has been substantially decreased, steel production has been increased, and fuel consumption decreased. Thirty years ago 190 to 225 lb. of limestone was used for flux per net ton of steel produced; by the early 1930's this had been cut to 120 to 140 lb. for most grades.)

2. Rapid methods of analysis for both steel and slag — including rapid wet chemical methods, carbon analyzers of various types, and the spectrograph — have been extremely valuable in improving steel quality. Steel composition is under more positive control by reason of more accurate and quicker analyses, thus speeding-up the working of heats.

3. Many worth-while studies on the thermochemical slag-metal equilibria have resulted in faster working of heats, more uniform deoxidation, decreased segregation, and cleaner steels.

4. Studies of deoxidation phenomena have led to more efficient and improved deoxidizers, not only to decrease the oxygen content of the steel, but also to produce special effects such as controlled hardenability, grain size, stabilization of carbides, and cleaner steels. One of the outstanding examples of this work has been the perfection of fully-killed, deep-drawing sheet steels, which has meant so much to the automobile industry. In this broad field the metallurgist has played a vital part in controlling and improving quality. At the same time, yield of the heavy tonnage steels as well as the more specialized steels has been increased.

5. Bath temperature measurements and control have been achieved with varying degrees of success through optical pyrometer readings on a "spilling spoon test" and on the tapping and pouring streams. Recent results from the Collins-Oseland pneumatic type photronic cell or infrared ray tube pyrometers are especially promising. The immersion type of platinum-rhodium thermo-

couple is probably the most accurate, and is quite widely used, despite the handicap of requiring a new silica protecting tube for each measurement. (The roof-bath temperature equalization method is also being studied at the present time.)

6. Successful efforts by management and metallurgical personnel to impress upon furnace crews the value of a good, open and live action between the bath and slag have gone far to improve steel quality.

7. Injecting gaseous oxygen directly into the bath to effect rapid carbon drop has shown some very interesting results. Detailed metallurgical studies of production heats are now in progress.

8. Statistical analysis is being widely applied and has gone far in developing new concepts and in disproving erroneous ones.

Pit Practice — The gradual enlargement of furnace capacities has been accompanied by changes in handling steel at the pit side from the moment the tap hole is opened. Metallurgical standard practices have been established over the years for each grade of steel produced. Today an observer follows each heat throughout its processing and makes a written record of it for any future development. Thirty years ago, such a procedure was practically unknown.

Present-day ladles of over 200-ton capacity compare to the 100-ton units formerly used. Studies are continually in progress on refractory linings, stopper heads, sleeves, and nozzles. Nozzle sizes for pouring the many sizes of ingots produced by Carnegie-Illinois in the Chicago District have been studied for many years to determine the proper rate of teeming for the desired ingot qualities. Thus, nozzles have been increased in length from 9 to 13 in. and in diameter up to 3½ to 4 in. for the pouring of certain grades of steel where 2 to 2½-in. nozzles were formerly used.

At the same time there have been comparable increases in sizes of the stopper head, pin and rod — in fact, the entire stopper rigging has been greatly improved and made more rigid. During the past 15 years, stopper heads containing 15 to 20% graphite have been found to decrease erosion, reduce the number of leaky pours and assist in the production of cleaner, better quality steel. Until 1934 the weight of the sleeve was carried on the stopper head. Today the shoulder-type stopper rod carries the weight of the sleeves, thereby substantially improving teeming practice.

The Authors: Division Superintendents of Steel Production

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Gary Works

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Another item which may not at first seem important, but which has been of great value in improving pit practice, has been an improved drying oven for properly heating and drying stopper rods. Workmanship, both in the manufacture and application of pit refractories, has likewise improved and a better appreciation of the possibilities, as well as the limitations of ceramic products, has been of great value in developing better refractories.

During the past 30 years many studies have been made in the Chicago District to ascertain ingot mold designs which would produce the most satisfactory ingots. The trend has been away from smooth-walled molds. The effect of various depths of flutes and corrugations has been studied, as well as the effect of changing the taper of the inside walls. Radical changes in corner and flute radii have resulted from these investigations.

Mill Routines — Throughout the processing of steel from the openhearth through the primary and finishing mills, metallurgical inspection and studies are made nowadays to determine whether

11 YEARS IN SALT WATER

THE WELDED SPECIMEN, on the right, was part of a model gasoline tank designed for use with salt water ballast. Partially immersed for 4½ years in the polluted harbor at Newport News, Va., it was tested along with several other materials, and proved outstanding among the few that withstood this exposure without appreciable damage. After the Newport News tests, this specimen was continuously exposed for another 6 years, partially immersed in flowing sea water at Kure Beach, North Carolina.

Its companion specimen, made of the same alloy containing 70 per cent copper and 30 per cent Nickel, was similarly exposed at Kure Beach for 11 years. The rate of corrosion was the same for both specimens ... only 0.0002" per year. These specimens are permanently displayed in the Inco Marine Test Station at Kure Beach.

Exposed to sea water for more than a decade, these two specimens show the remarkable corrosion-resistance of both welded and unwelded 70-30 cupro-Nickel alloy.

Welds ... including butt, fillet and tack welds ... performed as well as the rest of the alloy, reflecting its natural weldability and inherent corrosion resistance.

Although primarily developed for use in marine condenser tubes, this alloy is particularly useful for large diameter piping, water boxes, tanks, sheathing and similar forms.

It is strong, tough, and not susceptible to dezincification nor subject to stress corrosion cracking. It sturdily resists both pitting and erosion (impingement attack).

Full information is available upon request and we invite your inquiries.

EMBLEM OF INCO SERVICE

TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information is yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

"H" Steels; Chemical Composition Ranges

(Electric Furnace or Openhearth Bars, Billets or Blooms) **Revised June 1947**

S.A.E. or A.I.S.I. Designation	Chemical Composition (Subject to Permissible Variations)					
	C	Mn	Si	Ni	Cr	Mo
1320 H	0.17/0.24	1.50/2.00	0.20/0.35	—	—	—
1330 H	0.27/0.34	1.50/2.00	0.20/0.35	—	—	—
1335 H	0.32/0.39	1.50/2.00	0.20/0.35	—	—	—
1340 H	0.37/0.45	1.50/2.00	0.20/0.35	—	—	—
2512 H	0.08/0.15	0.35/0.65	0.20/0.35	4.70/5.30	—	—
2515 H	0.11/0.18	0.35/0.65	0.20/0.35	4.70/5.30	—	—
2517 H	0.14/0.21	0.35/0.65	0.20/0.35	4.70/5.30	—	—
3310 H	0.07/0.14	0.35/0.65	0.20/0.35	3.20/3.80	1.35/1.75	—
3316 H	0.13/0.20	0.35/0.65	0.20/0.35	3.20/3.80	1.35/1.75	—
4130 H	0.27/0.34	0.35/0.65	0.20/0.35	—	0.80/1.15	0.15/0.25
4132 H	0.30/0.37	0.35/0.65	0.20/0.35	—	0.80/1.15	0.15/0.25
4135 H	0.32/0.39	0.60/0.95	0.20/0.35	—	0.80/1.15	0.15/0.25
4137 H	0.35/0.43	0.60/0.95	0.20/0.35	—	0.80/1.15	0.15/0.25
4140 H	0.37/0.45	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4142 H	0.40/0.48	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4145 H	0.42/0.50	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4147 H	0.44/0.52	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4150 H	0.46/0.54	0.70/1.05	0.20/0.35	—	0.80/1.15	0.15/0.25
4317 H	0.14/0.21	0.40/0.70	0.20/0.35	1.50/2.00	0.35/0.65	0.20/0.30
4320 H	0.16/0.23	0.40/0.70	0.20/0.35	1.50/2.00	0.35/0.65	0.20/0.30
4340 H	0.37/0.45	0.60/0.95	0.20/0.35	1.50/2.00	0.65/0.95	0.20/0.30
4620 H	0.17/0.24	0.40/0.70	0.20/0.35	1.50/2.00	—	0.20/0.30
4640 H	0.37/0.45	0.55/0.85	0.20/0.35	1.50/2.00	—	0.20/0.30
4812 H	0.10/0.17	0.30/0.60	0.20/0.35	3.20/3.80	—	0.20/0.30
4815 H	0.12/0.19	0.35/0.65	0.20/0.35	3.20/3.80	—	0.20/0.30
4817 H	0.14/0.21	0.35/0.65	0.20/0.35	3.20/3.80	—	0.20/0.30
4820 H	0.17/0.24	0.45/0.75	0.20/0.35	3.20/3.80	—	0.20/0.30
5140 H	0.37/0.45	0.60/0.95	0.20/0.35	—	0.65/0.95	—
5145 H	0.42/0.50	0.60/0.95	0.20/0.35	—	0.65/0.95	—
5150 H	0.46/0.54	0.60/0.95	0.20/0.35	—	0.65/0.95	—
6150 H	0.46/0.54	0.60/0.95	0.20/0.35	—	0.80/1.15	(0.15 min. V)
8617 H	0.14/0.21	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8620 H	0.17/0.24	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8622 H	0.20/0.27	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8625 H	0.22/0.29	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8627 H	0.25/0.32	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8630 H	0.27/0.34	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8632 H	0.30/0.37	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8635 H	0.32/0.39	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8637 H	0.35/0.43	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8640 H	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8641 H*	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8642 H	0.40/0.48	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8645 H	0.42/0.50	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8647 H	0.44/0.52	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8650 H	0.46/0.54	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8655 H	0.50/0.60	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8660 H	0.55/0.65	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8720 H	0.17/0.24	0.60/0.95	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8735 H	0.32/0.39	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8740 H	0.37/0.45	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8742 H	0.40/0.48	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8745 H	0.42/0.50	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8747 H	0.44/0.52	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8750 H	0.46/0.54	0.70/1.05	0.20/0.35	0.35/0.75	0.35/0.65	0.20/0.30
9260 H	0.55/0.65	0.70/1.05	1.80/2.20	—	—	—
9261 H	0.55/0.65	0.70/1.05	1.80/2.20	—	0.05/0.35	—
9262 H	0.55/0.65	0.70/1.05	1.80/2.20	—	0.20/0.50	—
9437 H	0.35/0.43	0.85/1.25	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9440 H	0.37/0.45	0.85/1.25	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9442 H	0.40/0.48	0.95/1.35	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15
9445 H	0.42/0.50	0.95/1.35	0.20/0.35	0.25/0.65	0.25/0.55	0.08/0.15

*Sulphur content 0.040/0.060

Permissible Chemical Variations

Phosphorus and sulphur in openhearth steel to be 0.040% max. each, except in 8641 H.

Phosphorus and sulphur in electric furnace steel to be 0.025% max. each, except in 8641 H.

Small quantities of certain elements may be found in alloy steel which are not specified or required. These elements are to be considered as incidental and acceptable to the following maximum amounts: Copper 0.35%, nickel 0.25%, chromium 0.20%, molybdenum 0.06%.

The chemical ranges and limits shown are subject to the standard permissible variations for check analysis over the maximum limit or under the minimum limit. These permissible variations for sections of 100 sq. in. or less are: 0.01 for carbon up to and including 0.30%, 0.02 for over 0.30%; 0.03 for manganese up to and including 0.90%, and 0.04 for over 0.90; 0.005 for either phosphorus or sulphur; 0.02 for silicon up to and including 0.35%, 0.05 for over 0.35%; 0.03 for nickel up to and including 1.00%, 0.05 for nickel over 1.00 up to and including 2.00%, and 0.07 over 2.00%; 0.03 for chromium up to 0.90% inclusive, and 0.05 for chromium over 0.90%; 0.01 for molybdenum up to 0.20% inclusive, 0.02 for molybdenum over 0.20%.

General Notes

These compositions apply to steels produced to tentative hardenability bands (Data Sheets 19 to 24), determined by the standard end-quench on 1-in. round bars (Data Sheet 55), and to steels manufactured to "fine-grained steel practice".

Size and Shape Limits: 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight.

Hardenability of steels may be specified in several ways: *(a)* Max. and min. distances on Jominy bar for any desired hardness; *(b)* Max. and min. hardness at any specified distance; *(c)* Two max. hardness values at two desired distances; *(d)* Two min. hardness values at two desired distances; *(e)* Any point on min. hardenability curve plus any point on max. curve. In addition to any of the above, the hardness limits at 1/16 in. may be specified.

Quality Conditions — All conditions and quality features, except as detailed above, shall be in accordance with the regulations shown in the American Iron and Steel Institute's "Steel Products Manual", Section 10 on Alloy Steels.

the practices are performing satisfactorily. Surface conditioning of primary mill products is now standardized in the Chicago District according to the grade of steel and the purpose and type of future processing and application it will receive by the mill and customer. Standards have been established for heating times and temperatures for each grade of steel. Scarfing and yield practices are now being reviewed by statistical methods to find out whether still further improvements may be made. (Modern methods of statistical analysis have become a very important tool in the hands of the steelmaker and increasing use is being made of them in the steel industry.)

While the use of alloy steels was known to ordnance experts during the latter part of the last century, it was not until the first decade of the present century that alloy steels began to be explored for their full possibilities to industry generally. The development of the automobile spurred investigation, and alloy steels were widely applied in motorcar gearing, drive mechanisms and springs because of a continual demand for tougher and stronger steels. Other industries, such as the railroads and aircraft, which adopted the weight saving and corrosion resistant alloy steels (as well as implement manufacturers, the oil industry, and scores of other users) have contributed a large share to the exploration of the effects of those elements that go into the composition of alloy steels on the behavior of those steels during use.

Much alloy steel is made in electric furnaces. Few metallurgists in the consuming industry, however, realize what a large fraction comes from the openhearth. Impetus was given to the development of openhearth alloy steels in the Chicago District during the middle 1920's by the ever-growing demands which necessitated close adherence to metallurgical controls during manufacture. Among these were the innovation of grain-size control during the late 1920's and, later, hardenability control which has been developed to specification status within the past few years.

Grain-size control served to enhance the heat treating properties. By proper and exact grain-size control during the steel processing, an important step was made in the general improvement of alloy steels. In this development program, research conducted at Carnegie-Illinois plants in the Chicago District played an important part. Metallurgically, the "tailor-made" steels came into being. Constant research and the search for better and better alloy steels saw the advent of hardenability control and its practical introduction into the openhearth phase of steelmaking. Much of the former guesswork in quality control and exactness of the finished alloy products was removed by these two metallurgical innovations — grain-size and hardenability control.

During World War II, experimental and development work was accentuated and the production of steels to meet the requirements of modern warfare was increased to a rate formerly deemed impossible. Aircraft steels demanded the utmost in production practices, inspection, and quality control. The "national emergency" (N.E.) steels were brought to a high degree of quality, and production as well, to meet the urgent demands of industry, making our country's limited supplies of alloys reach further, without interfering with the qualities so necessary to the steels required for the successful prosecution of the war.

Chief Metallurgists for Carnegie-Illinois

E. W. Pierce
South Works

C. J. Hunter
Gary Works

Iron Foundry Advances in the Chicago Area

By H. Kenneth Briggs
Sales Metallurgist
Miller & Co., Chicago

Naturally the most impressive mechanization and metallurgical control may be found in the largest foundries and the specialized jobbing shops. However, the industry generally could not have met its wartime responsibilities unless the principles of technical and scientific operation were widely understood. Improved melting equipment, new combinations of furnaces for continuous melting, close control of carbon by inoculation but especially by the chill test, represent outstanding achievements of the last decade.

IN ANY review of related occurrences over a period of time the more recent happenings loom largest in the perspective. This cannot be escaped by any contemporary observer — particularly one, like the present author, who has been connected with the regional industry he is writing about hardly half the 30 years he is expected to review. Thus he attempts to disarm his critics in advance. If the events of the last 10 years indicate rather large advances in the foundry industry around Lake Michigan (even though the advances may be confined to a relative few of the many plants), it is obvious that these improvements could not have been made unless an enormous amount of preliminary work had been done through the years by unknown and unsung managers, production superintendents, chemists and metallurgists. A good leaven of progressive men must always prepare the way for any substantial advance.

The manufacturing industries of the Chicago area include almost every conceivable kind of plant, and most of them are served by foundries making gray iron, malleable or steel castings. The Chicago foundry area may be said to include almost the entire area adjacent to the southern end of Lake Michigan, reaching up the west side of the lake to include Milwaukee and up the east side to include Muskegon. It is only natural that the great agricultural areas of Illinois and Indiana should have caused the early manufacture of agricultural implements and tractors around the southern end of the lake. The automobile industry, centering in Detroit, gave rise to a preponderance of automotive production along Lake Michigan's eastern shores, and a more mixed production of electrical and heavy machinery and machine tool castings along the western shore. For example, Milwaukee includes a concentration of notable steel foundries.

These plants still include many small shops employing but a few men working mostly with hand tools and few mechanical aids. There are also a number of intermediate sized shops that utilize molding machines, and a few very large tonnage shops which are mechanized to the fullest possible extent. Altogether there are, in this great foundry area, examples of every type production method known, so the changes and advances of this area are representative of the entire ferrous foundry industry in the United States.

The great range and variety of mechanical aids are quite obvious to the most casual observer. Less apparent are the metallurgical operations that might be noted only by the expert. To my mind the most striking proof of the proposition that — through the years between the two big wars — the entire foundry industry had reorganized from a rule-of-thumb operation to one under technical control, is the way it could respond to confusing wartime "directives" from Washington.

The immediate result was for many gray iron foundries to change the class of output. Stove and furnace shops changed for the duration to

jobbing and machine tool castings, many makers of household equipment castings made automotive and machinery castings, agricultural implement shops produced automotive castings, and the better equipped general jobbing shops turned to work which required fairly close chemical limits and better control of molding operations. The general result has been to broaden the knowledge of how to make castings of close chemical control and better molding practice.

Malleable Iron

Another instance of the war's interference with "normalcy" occurred early in 1942, when the Chicago Ordnance District advised malleable foundries to convert to steel — or close for the duration. It is a matter of record that a year later the War Production Board had to authorize the greatest mechanization of malleable foundries in history — a movement that has not yet spent itself, since available foundry labor is still in short supply as of mid-1947.

Incident to the intense mechanization of many malleable foundries, the extremely long annealing cycle of malleables was materially speeded by using higher malleableizing temperatures, a little more silicon in the metal to speed graphitization, and controlled atmosphere furnaces of the tunnel type. Several installations are heated by butane gas. A fortunate circumstance is that the annealing process itself conditions its own atmosphere. Instead of requiring highly precise control of prepared atmosphere — as would be needed for bright hardening of alloy steel — the reactions between gas and malleable in the various stages of its continuous annealing seem to adjust themselves so the product emerges without surface damage.

Mechanized and continuous molding requires continuous melting rather than the intermittent melting of cold charges in the air furnace — the hitherto melting equipment for "certified" malleable castings. Continuous primary melting in the cupola now provides molten iron for the air furnace. The cupola charge is scrap steel and shop returns plus auxiliary silicon (silvery pig iron or ferrosilicon briquettes). Since the carbon, picked up from the cupola, is higher than is wanted in malleable, it is adjusted by holding the molten metal for a definite time in the air furnace, where it is lowered by the oxidizing atmosphere to the desired analysis.

Impetus was also given, during the rushing war years, to pearlitic malleable, wherein the matrix remains pearlitic rather than being fully malleableized. Strength is about 50,000 psi. or better with 8 to 10% elongation.

Improved Melting Methods

One recent malleable installation contains a hot blast cupola equipped with air-weight and moisture controls. The melt is accumulated in an electric furnace where it is adjusted to analysis and temperature.

Years ago the chilled car wheel industry developed the hot blast cupola, wherein air going into the cupola through the tuyeres is preheated to some temperature between 400 and 700° F. This is usually accomplished by burning cupola stack gas in a recuperator. Higher metal temperatures are attained with a substantial saving of coke. Hot blast cupolas are now coming into use in shops which melt all day, and have sufficient tonnage to amortize the investment in a reasonable number of years. They prevail in the piston ring industry.

"Air-weight controls", which automatically deliver a desired volume (cu.ft. per min.) or weight (lb. per min.) from the blower to the cupola, definitely improve the consistency of cupola operation. They are applicable to either hot or cold blast cupolas. Automatic units are also available to control the moisture in the air blast. They, too, can be used on either the hot or cold blast. While not in as general use as the air-weight control, they are common in piston ring foundries.

As a result of its very high economy, the cupola is, of course, the almost universal melting unit in the gray iron foundry. Probably cupola melters will never attain the precise chemical control of openhearth or electric steelmaking furnaces, but with increasing attention to the details of its operation we are getting much closer chemical control. Higher melting temperatures are prevalent; this means cleaner iron. The hot blast, air-weight and moisture controls are notable aids to secure a quality product. Receiving ladles or forehearths, that hold about three molten cupola charges, average out the analysis of the iron; they also are valuable for desulphurizing. A few foundries run the metal from the cupola continuously into an electric furnace which acts as a forehearth and where higher metal temperatures can be attained.

Several foundries met the sudden wartime demand for steel by installing triplex melting units in which primary melting is done in the efficient and low cost cupola, the product of which is gray iron. The carbon and silicon of the gray iron are then oxidized in the converter, the result being steel. Several blows from one or more converters are accumulated in large electric furnaces to average out the somewhat varying analysis, to adjust

the temperature, to serve as a storage reservoir and to introduce alloys when desired. Extensive heat treating furnaces for annealing, normalizing and tempering of steel castings accompany the melting equipment.

Carbon Control in Gray Iron

Aside from iron and silicon, carbon is the single most important element in determining the properties of gray cast iron. In general, carbon in cupola iron is varied from about 2.90 to 3.50%. Its appearance in the casting's microstructure can also be varied — whether combined carbon or graphite — either by heat treatment, which is seldom done, or during melting by the adjustment of analysis and cupola melting, or by pouring practice. For example, higher steel mixtures going into the cupola produce molten iron lower in carbon. The adjustment of silicon upward results in more graphite and vice versa. The proper use of alloys helps control the carbon by increasing (or decreasing, as the case may be) the presence and stability of the pearlite and carbides, or by increasing the toughness of the ferrite matrix.

Each type of gray cast iron exhibits certain "chill" characteristics; that is, each shows a certain depth of chilled white iron when cooled rapidly enough by casting the metal against a small cold chill block, or in a V-shaped dry sand mold or core. Such "chill controls" are standard practice in shops working to close chemical and physical limits. If the iron is too hard, as shown by a deeper chill, ferrosilicon is added to the ladle; when the chill is too low and the iron therefore too soft, ferrochromium is added to harden it. Each tap or each ladle can be "chill tested" and, if critical enough, adjustment can be made before that iron is poured. The foundryman thus can have a continuous picture of his entire heat. It is a wonderful aid for making castings of uniform quality.

Like ladies' hats, we have styles among the metallurgical brethren. Currently foundry metallurgists are paying very much attention to "inoculation". Several elements either singly or in combination when added to the molten gray iron at the cupola tend to precipitate the carbon as stringers (Type A graphite*) rather than rosettes or eutectiform graphite. The graphitizing elements (silicon and carbon) tend to form more graphite and less combined carbon, while the stabilizers (chromium and manganese) tend toward more combined carbon. By the proper use of inoculants — alloys containing these elements — the properties of a given cupola base iron can be altered considerably. Chill tests are used to regulate and standardize the amount added. To promote more uniform chills, the chilled car wheel industry quite generally adds tellurium and graphite to the ladle.

*Joint Specification of American Foundrymen's Association and American Society for Testing Materials. See *Metal Progress* Data Sheet for April 1947.

Alloy Irons

Alloys have a proper field in gray cast iron. Gray iron can be heat treated in about the same manner as steel but the vast tonnage of plain and alloy cast iron is used in the as-cast condition. Since gray cast iron is a matrix of steel broken by random graphite stringers or pieces, alloys have a profound influence on the steel matrix in the same fashion as steel itself is altered by their use, and according to the same metallurgical rules. This is in addition to the influence which alloys have on the amount and distribution of graphite and combined carbon in this steel matrix.

Where tonnage warrants, alloys can be introduced as a part of the cupola charge or they can be added to the ladle as required. Chromium, nickel, copper and molybdenum are used in some motor cylinders, brake drums, clutch plates and other castings that are subjected to wear. Cylinder liners for heavy duty diesels are made of fairly complex alloy composition and are heat treated by normalizing, quenching and tempering. Cast crankshafts and camshafts are extensively used in automotive and diesel engines. Such castings involve but a minimum of machine finish compared to forgings. They are made in complex alloy compositions and are subjected to full heat treatment to develop strength, hardness and elastic properties. Flame and induction hardening are extensively used to harden bearing surfaces.

For many, many years it was the practice for foundries to "age" heavy castings such as machine tool bases by standing them in the yard for six months to relieve the casting strains so the parts would not warp during machining. Now this aging is accomplished at will by heating them to 900 to 1100° F., soaking and cooling to nearly room temperature in the heat treating furnace. Many smaller castings to be machined to tolerances measured in ten thousandths are also strain relieved.

Conclusion — The above is but a sketchy picture of occurrences within the last 10 years. The historical steps leading up to the present level are not noted, even in a single branch of a highly complex industry. It is to be repeated, however, that none of these things sprung full blown from the brow of Jove; each represented a slow growth fostered in no small part by the intelligent technical men in the Chicago area.

Die Steels and Their Treatments Pace Drop Forge Industry

By **Alfred F. Finkl**
Vice-President
A. Finkl & Sons Co., Chicago

Drop forgers, to meet increased demands from the expanding machinery builders, are requiring more durable die steels — harder, yet more machinable. The trend in 30 years has been away from plain carbon and the nickel and chromium steels, to carefully balanced triple-alloy steels (Ni-Cr-Mo), with copper added more recently to improve machinability in the hardened condition. Full advantage is also taken of present-day knowledge of isothermal transformation, heat transfer by convection, automatic instrumentation, and scientific quenching schedules when handling these large masses of highest quality steels.

IN CORRESPONDENCE leading up to the writing of an article about the forging industry, the Editor outlined the basic theme of this entire issue as follows:

"Since the ⊕ sprang from roots in Detroit and Chicago, and since the Chicago group was organized just 30 years ago, the general theme of the pre-convention issue of *Metal Progress* will be the 30-year development of the Chicago region as a manufacturing center, not only of fine metal and metallurgical accessories, but of machines and equipment made of metal. This can be done by a group of articles emanating from leading firms in the respective lines. Their stories would have this in common — that an essential role has been played by metal of ever higher quality, and by metallurgists of progressively broader information and equipment. This whole movement, indeed, is not unique to the Chicago area, yet the Chicago story is representative and gears in with the forward march of the national economy, and the well-being of Americans generally."

This invitation to describe a general trend in terms of a specific organization encouraged us to respond by giving an account of the drop forge industry — not because we have encyclopedic information about this complicated subject, but because of our belief that the entire industry has progressed more or less in parallel with improvements in forging equipment, and especially of hammers and die blocks. On that last item we do believe we are well informed.

Statistically, the progressive growth of the drop forge industry has been in direct proportion to the volume increase in the mass production industries. In 1921, when the earliest figures became available, the production of drop forgings required 0.9% of the year's total ingot capacity, while in 1946 it required 1.5% of the total ingot capacity. Thus, there was not only a great increase in tonnage due to the expanded capacity of the steel industry to nearly 100,000,000 tons a year, but the *relative* importance has nearly doubled.

This higher ratio of drop forging production is due to the volume increase in automobiles and trucks, the mechanization of farm and road building equipment, as well as the greater number of machine tools in use today. Such an increase in the mass producing industries demanded not only great productivity, but also required that forgings be furnished to more uniform dimensional and

weight tolerances than ever before. This was necessary because, for the greater part, the forgings were machined out in automatic centering and chucking tools.

For this reason the problems that had to be overcome with the advent of the automotive age can be readily understood. They centered about the triple demands of higher quality, greater tonnage, and closer size accuracy. The last two of these tie in directly with the quality and durability of the forging dies.

In 1917, when the Chicago "Steel Treaters" organized, carbon steel die blocks were used to a larger extent as hot work tools than were the alloy steel types. The carbon content ranged from about 0.40 to about 0.70%. The impressions were sunk in the annealed blocks and, with luck, the dies were subsequently hardened.

Hardening of dies was then rightly considered an art. The heat treater accomplished this task more often than not without the aid of temperature measurements, and scarcely any means for testing the hardness after heat treating. Standard equipment for the die hardener consisted of a magnet, a file, and possibly a scleroscope. Breakage from quenching occurred so often that a die hardener who avoided this disaster — most of the time — was considered something more than just a normal human being well versed in his trade or profession.

Advances in Alloying

But even as early as 1917, alloyed steel die blocks were furnished of a nickel-chromium analysis similar to the A.I.S.I. 3100 series (1.3% Ni, 0.65% Cr), as well as 3½% nickel steels similar to the present-day A.I.S.I. 2300 series and chromium-vanadium analyses similar to the 6100 series (1% Cr, 0.15% V).

Die blocks with sections up to a 10 or 12-in. cube were quenched and tempered back to a hardness of about 45 scleroscope. With the machine tools and cutters then available, this was about the top of the machinability range. Die blocks with larger sections were merely normalized in air and not tempered. No attempt was made to control the hardness of these blocks of larger section by a quench and draw, yet it was possible to produce finished dies with hardness in excess of 30 scleroscope.

Viewed in retrospect, it can be seen what a developmental job was ahead of William Finkl (now president) when he entered the organization in 1919 as chief chemist and metallurgist. His big and immediate job was to show how to manufacture a better die block, one that would provide longer production and more satisfactory service.

As many readers can remember, alloy steels in larger sections (over 3 in.) were left very much

Battery of Furnaces in New Heat Treatment Department, With Oil and Water Quench Tanks in Foreground. At far right are two hammer rams on furnace car bottom

alone in those days because of their sensitivity to flakes or thermal ruptures. The higher the alloy content, the more sensitive the steel. Despite these obstacles, Bill developed an air hardening alloy steel capable of 45 to 50 scleroscope in larger sections after a normalize and relatively high draw. A typical analysis was 0.50% C, 1.6% Ni, 0.8% Cr and 0.9% Mo. Its production started in 1919, and thus antedates the so-called "triple alloys" by many years. Later it was trade named "Durodi". It was such a great advance over previous materials used for heavy hot work dies that it received wide acclaim.

This increase in hardenability,* however, made the product more sensitive to flake and rupture than the lesser alloyed competitive grades, but the foreseeable demand for better hot work die steel was great enough for the company to exert every effort to overcome this harmful defect. During 1920 and 1921, our metallurgical department, working with the splendid cooperation of the steel suppliers, found out the cause and some of the cures to this problem. Today, the heavy steel industry still has the hazard of flake or rupture in alloy steel but the reasons for it are well known, and the corrective measures are firmly established even in so common a thing as rail steel.

As our knowledge of the hardenability of these complex alloys increased, we were able, late in 1920, to design and install drastic water and oil quenching systems, and offer the first totally quenched and tempered die block.

Further developments made by Bill Finkl and his metallurgists during the 1920's included other nickel-chromium-molybdenum analyses, with the carbon and alloy contents varied as required for individual needs of die blocks and hot work steels.

In addition, a suitable steel for heavily stressed forgings, such as drop hammer piston rods and upsetter cranks, was patented and marketed as "CNM", an analysis which was the forerunner of the present A.I.S.I. 4300 series of nickel-chromium-molybdenum steels.

The problem of machinability was also tackled. Of course, the average die shop's ability to work harder and harder blocks was continually increasing, but the aim would be a block that was fully hardened to a depth well below any reasonable impression, yet capable of being machined in the hardened condition. The answer was found by the middle 1930's as a modified A.I.S.I. 4350 steel, wherein about half the nickel was replaced by 1¾% copper. This steel ("Cu-Pro-Die") is machinable up to 477 Brinell.

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*In 1920, it may be remembered, that very phrase "increase in hardenability" would have required a lot of explanation. In contrast, the present widespread use of the Jominy hardenability test and knowledge of the influence of the various alloys on hardenability are in themselves significant measures of metallurgical progress.

Charging End of New Furnace for Isothermal Annealing Cycles, Showing Car Bottom and Method of Loading and Supporting Work in Process

Early in the 1940's another new hot work die steel was introduced under the trade name "Shelldie", with analysis of 5% Cr, 2.50% Mo, and 1% Si. While Shelldie was principally intended for use as punches in the production of our vast shell program, its resistance to wear and heat has since made it invaluable in many other hot work applications.

Viewed in their entirety, these improvements in dies might be thought to be sufficient for the forward-moving drop forge industry. However, our firm realized that greater production with closer tolerances was still the watchword of the day. Likewise we were sure that the last word had not yet been said about die steels. So about five years ago we entered into an agreement with Armour Research Foundation of Illinois Institute of Technology to study all phases and processes for improvement of hot work die steel used by the closed die forging industry. We believe that this institution, well equipped with facilities and personnel for metallurgical, chemical and physical investigations, will be able to carry on beyond the limits of our own more modest metallurgical department.

It should not be thought that the problem of better die blocks can be solved merely by improved steelmaking processes and perfected analyses. It is only natural that the diemakers should profit from the greatly enlarged knowledge about the theory and practice of steel treating and the vastly improved furnaces and instrumentation.

Finkl's Booth at the First "Metal Show", Chicago, 1919. William Finkl, metallurgist (now president of the firm), at right, with A. R. Lane, forge shop superintendent (now vice-president in charge of operations)

Advances in Heat Treatment

Early in 1946, two completely new heat treating plants were started by A. Finkl & Sons Co. and early in 1947 they were put into operation. All the ideas and requirements of precision die block heat treating that over 35 years of die block production have taught us have been incorporated into these new facilities. A few highlights of these most modern heat treating plants include:

1. Isothermal annealing after forging to control thermal ruptures and prepare the structure of the steel for subsequent heat treating.
2. Furnaces designed especially for heat treating die blocks to close hardness ranges by improving the radiation and convection of heat input to the charge.
3. Fully automatic pyrometric program control equipment.
4. Extremely drastic water and oil quenching systems with full automatic temperature and volume control of the quenching medium to assure duplication of highly developed heat treating procedures.

All useful methods of testing for hardness, structure, and strength are regularly employed, as well as the Sperry supersonic reflectoscope for verifying subsurface soundness. This latter method of testing assures us that the material passing inspection does not have such injurious defects as internal pipe or thermal ruptures.

We at Finkl's feel that, by the constant improvement in our production facilities and the beforementioned research program, we are doing our part, in no small way, to further develop new methods and means to promote greater production for the drop forge industry at lower costs. This, we believe, will contribute materially to the greater prosperity and well-being of all the peoples in our great nation.

Furnaces and Instruments

Photo Courtesy Lindberg Engineering Co.

Notable Advances in the Chicago District

Advancements in Industrial Heat Treating Equipment

By LeRoy A. Lindberg
President, Lindberg Engineering Co.
Chicago

In this article the author, a leader in the Chicago Chapter ⊕ as well as a leader in the industrial furnace manufacturing industry, emphasizes the contrast between the best the 1917 heat treater had in the way of furnaces and the perfected 1947 equipment that prepares a correct atmosphere (either in small or large quantity, to protect absolutely or to make desired surface changes in tools or machine parts in process), and furnaces — operating at all levels up to 1800°F. — that transfer all their heat to the work by means of a cyclonic rush of hot protective atmosphere. He also cites furnace brazing as an outstanding improvement — a byproduct of the knowledge about reactions between gas and hot metals.

IN 1917, with the United States mobilizing for the first World War, heat treating almost overnight assumed a new importance, for that war turned into the world's first mechanized conflict. Industry had to rush production of great numbers of bigger and better guns, ships, and trucks — quantities beyond the imagination of even the most ambitious. And a new, sprouting industry contributed airplanes, a new weapon that was soon to revolutionize warfare.

The metallurgist and heat treater of 30 years ago were depended upon as never before, because the parts of this new war machine had to stand up well under most rigorous conditions.

With the heat treating tools that American manufacturers offer today, such a job would have been immeasurably easier. In 1917 the heat treater had, by comparison, almost primitive tools. The direct-fired or semimuffle gas furnace was just about his one and only piece of furnace equipment, and he used it for both hardening and tempering. Protective atmospheres were unheard of.

Gas carburizing did not exist; packed bone and charred leather did the work. Nitriding was not to make its appearance for quite a few years. Conveyer furnaces, as we know them today, just didn't exist. Brazing was yet to be developed.

Light work was often tempered by placing it near an open furnace door, and watching it for temper color. Another method was to take light pieces (such as springs) from the oil quench, place them in a suitable container, put them back into the furnace chamber long enough to ignite the quench oil that remained, immediately remove them from the work chamber — and by the time the oil burned off they were tempered!

Another method (and one that still finds use) was the "tempering oil bath". Work was simply immersed in heated oil long enough to temper down to the desired hardness. The special oil had a high flash point, and for this reason could be heated to temperatures high enough for some tempering operations. Still other methods (also in use today) were tempering in molten salt, or molten lead. Treatments up to 1100° F. and even somewhat above could be handled in this way.

In shops where oil, salt, or lead tempering baths were not available, the heat treater usually put the cold work back in the old box furnace, and estimated when it was ready to remove. Precise temperature control, of course, wasn't possible with this method.

In World War II — with demands of industry that dwarfed those of World War I — the heat treater and the metallurgist again became "unexpendable". This time, fortunately, they had much more with which to work.

Three developments (100% forced convection heating, controlled atmospheres, and brazing) during the 25 years between wars did much to lift heat treating from the "blacksmith status" to its present place as a precise, exacting, and scientifically controlled process.

Between 1930 and 1935 the 100% forced convection furnace for tempering was developed and introduced.* This differed from the old radiant box-type furnace fundamentally in that heat (gas, oil, or electric) is generated in a separate chamber away from the work chamber but within the same furnace shell, and the heated atmosphere forced under pressure and at high velocity to the work chamber. Certain advances had previously been made in forced convection heating by installing fans of propeller type in the work chambers of electric furnaces, but the years between 1930 and 1935 marked the first activity in "100% forced convection heating" — that is, furnaces where *all* the heat reaches the work through the medium of a rush of hot atmosphere.

These furnaces are now well and widely known. No one doubts but that they produce work that is more uniformly heated throughout than is practicable in an old-fashioned direct-fired or radiant-heated furnace, and produce this superior product at a more rapid rate and at a lower handling cost.

Forced convection furnaces as originally developed were for operation up to 1250 or 1300° F. In 1939, research and development was started on a pit-type forced convection furnace that would operate as high as 1800° F. This furnace became available to industry late in 1941. It was then possible to use the "batch technique" for normalizing and hardening: Rather than handling work singly, it could be densely loaded on fixtures (Fig. 1) and lowered into the vertical work chamber for heating. For hardening, the pieces did not have to be quenched individually, as the fixture with the work load in it was quickly hoisted from the furnace and lowered into the quench tank. (As in the low-temperature forced convection furnace, heat was generated in a separate chamber, and there was no radiant heat to cause uneven heating and distortion.) Batch quenching, incidentally, brought forth new principles of quench tank construction wherein circulation was increased many fold to obtain the same uniformity of cooling that convection gives on heating.

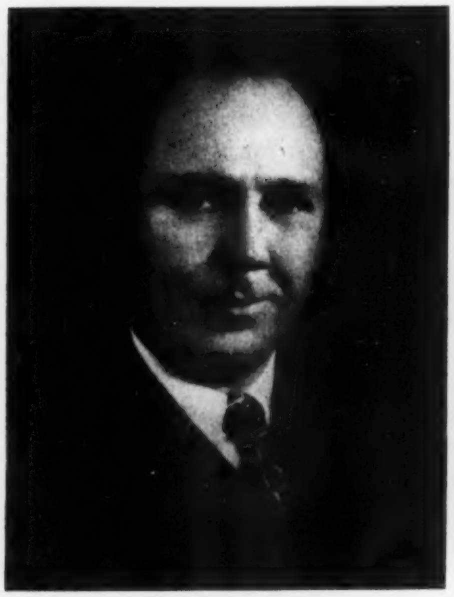
Fig. 1 — Operator Removing Charge of Worm Gears From High-Temperature (1750° F.) 100% Forced Convection Furnace. Entire work load and fixture are quenched together; an assembly that permits adequate circulation of atmosphere is also ideal for a rapid quenching operation

*Editor's Note — The article by John Ade on page 594 describes this furnace in its various embodiments in considerable detail.

Development of Controlled Atmospheres

Back in the days of World War I, the heat treater could do little about controlling his furnace atmosphere. Scale was considered a necessary evil and a normal result of heat treatment. Decarburization usually accompanied scaling, and plenty of extra metal was allowed for grinding and finishing operations. Extra metal, extra finishing in extra difficult operations, extra costs all up and down the line!

The little control that could be obtained over the furnace atmosphere in those early days was dependent upon the skill of the heat treater in adjusting the gas or oil burners. If they were carefully adjusted so that the final products of combustion resulted in about ½ to 1% of free oxygen, then the water-hardening and oil-hardening steels heated at 1450 to 1500° F. came out with a very light scale free from decarburization, *provided* the tools did not soak too long at heat. Since only a small percentage of the furnaces were equipped with indicating pyrometers and none had automatic control or gas analyzers, the above method of atmosphere control was dependent upon a keen eye for judging both temperature and combustion. The heat treater that could obtain a good batting average was an artist. As a rule the good heat treaters in those days considered themselves artists, developed corresponding temperaments, and did everything possible to keep their secrets from being passed down the line.



LeRoy A. Lindberg
President

Norbert K. Koebel
Research Director

Lindberg Engineering Co.

While the above method of atmosphere control enjoyed a degree of success by the comparatively few who were skillful enough to practice it, the development of the highly alloyed toolsteels, such as the high-carbon, high-chromium type which required higher hardening temperatures, soon outmoded it. Regardless of how the heat treater set the combustion, these steels would scale and decarburize badly. The tool had to be packed with cast iron chips or charcoal in an enclosed metal box — which, indeed, prevented scale and decarburization but suffered the great disadvantages of slow heating and no sure way of knowing whether the tool itself was up to the hardening temperature.

Promotion of the electric furnaces by utility companies seeking new outlets for electric power started the ball rolling on atmosphere control. Electric heat eliminated the undesirable products of combustion without the necessity of complicated and inefficient muffles and seals. It was then thought that all that had to be done was to flood the furnace chamber with a reducing gas and all the problems of scale and decarburization would be over. The heat treater soon found that reducing gases generated by incomplete combustion of fuel gas and air eliminated the scale, but strangely enough were more decarburizing than straight air or products of complete combustion!

From that day on, constant research has gradually improved furnace atmospheres to the precision controlled atmosphere of today. Furnace atmospheres are now doing the job that machine tools were required to do not more than ten years ago. Production parts are finished to exact size and heat treated totally free from scale and decarburization. Tools and dies of nondeforming steels, such as high-carbon, high-chromium analyses, may be finished to size and actually polished to a mirror surface before heat treatment and the protective atmosphere, during the hardening, quenching and tempering, prevents decarburiza-

tion and even discoloration. Tools of many standard analyses go into service for many applications without grinding or polishing. Oil-hardening and water-hardening tools and dies can be made to closer tolerances, and the time required in the old days to grind away the scale and decarburization is reduced from as much as a week's labor to a few hours', because the tools and dies need only a light final grinding or polishing operation to correct for deformation during hardening. Thus, labor and the machines for grinding, polishing, sandblasting, or pickling have been eliminated by a new machine — the precision controlled atmosphere furnace.

Once the furnace was developed, the next advance has been in the design of the equipment to meet the fundamental requirements of a protective atmosphere with a sense of economy, efficiency, and simplicity of operation.

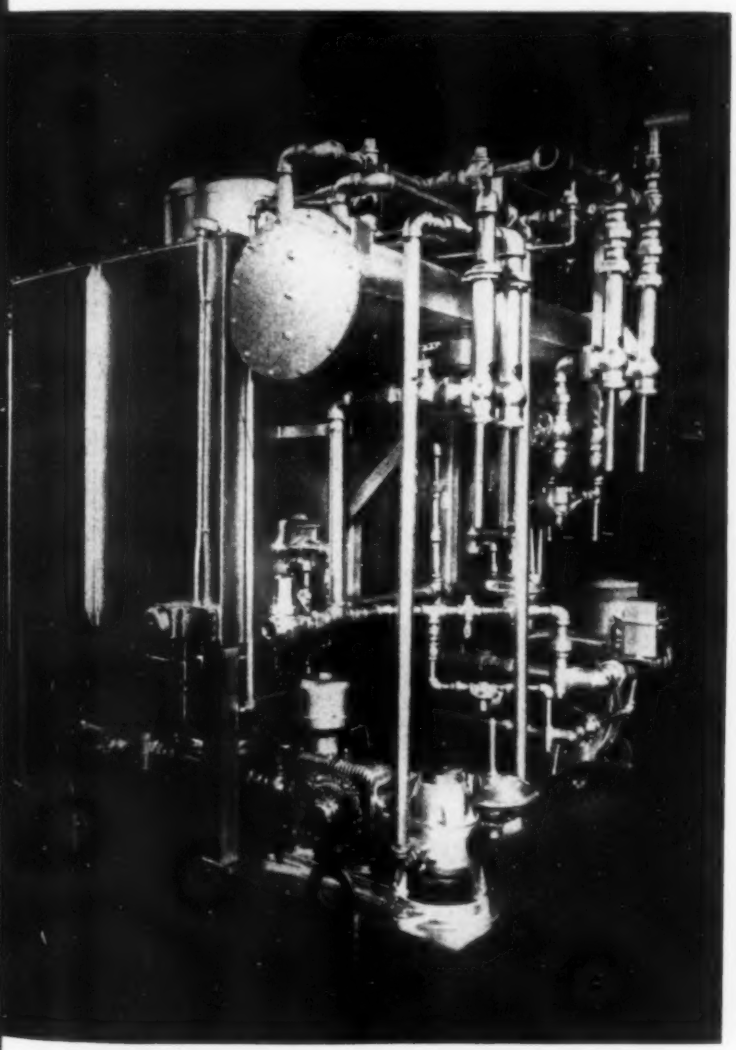


Fig. 2 — New Automatic, High-Temperature, Precision, Endothermic Gas Generator. This is a "central-station" type generator of 2500 cu.ft. per hr. capacity, and can be used to supply atmosphere to a number of furnaces

Atmosphere Generators

This development during the last seven to ten years of the simple, inexpensive charcoal-gas generator to its present high degree of efficiency has enabled the smallest tool room to afford a precision atmosphere for the heat treatment of the most complicated tool and die steels. This type of generator is particularly designed for the hardening of molybdenum high speed toolsteels. The charcoal gas generator of today resembles those of ten years ago in outer appearance only. Externally it resembles a domestic hot water heater, gas fired, and contains no more elaborate auxiliary fixtures. Improvements in the internal design of the refractories and of the charcoal preheat and gas take-off have increased its efficiency and the quality of the atmosphere by 100%. The proper type of charcoal has been intensively studied to eliminate variables and obtain a "consistent" atmosphere. Consequently, a highly purified grade of charcoal is now available from distributors throughout the country.

At the present day, the charcoal type of generator is restricted to the smaller toolroom furnaces and is being abandoned for the production heat treatment of medium-carbon or high-carbon steels — although it did good service during World War II for the want of a better method. The chief reason for this is the handling and storage space required for the charcoal necessary for the volume of gas demanded by large furnaces.

The outstanding development within the last few years has been in the perfection of protective atmospheres for medium and high-carbon steels by cracking city, natural, propane, or butane gases with air endothermically.* First attempts along these lines occurred some years ago, but it was found that the atmosphere was not too reliable for high-carbon steels and toolsteels, because a rich gas-air mixture was required and the generator would soot-up. Soot not only caused the generator to lose its capacity by the restriction, but also lose its ability to produce a gas of constant analysis; the soot "poisoned" the catalyst

*Editor's Note — The reader may wish to refer to Henry M. Heyn's article in August *Metal Progress* on precision control of the "endothermic" types of atmosphere.

the generator contained — a necessary aid to promote the correct gas reactions.

Research during the past five years has overcome the above difficulties and developed precision and fully automatic high-temperature gas cracking generators. A cracking temperature of 2200° F. (300 to 400° higher than previously used) insures a consistent analysis of effluent gas, free of carbon dioxide and extremely low in water vapor, without the danger of sooting-up the generator or catalyst. Refractory retorts with the proper seals had to be developed to replace alloy retorts previously used.

This in itself was an outstanding achievement, because several of the theorists claimed that "It could not be done"!

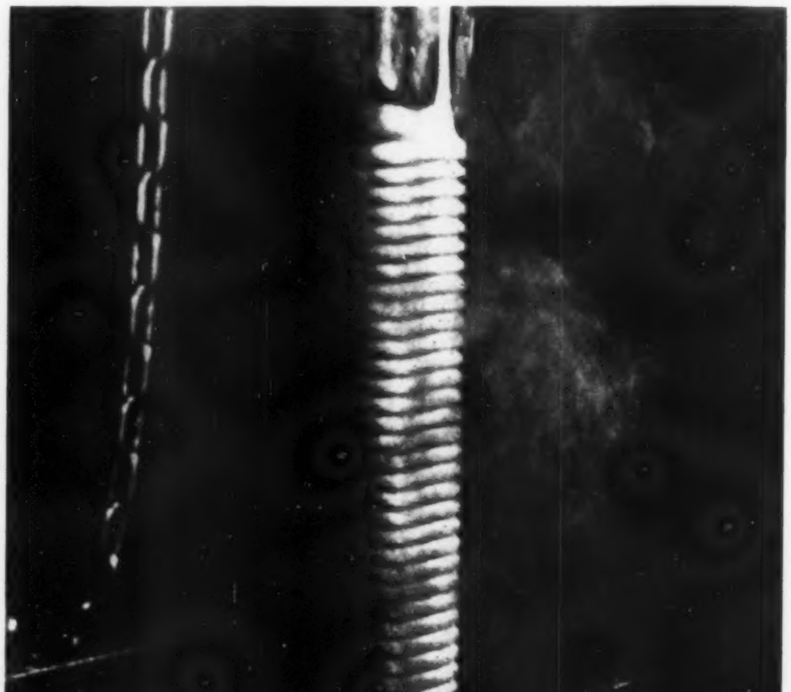
The new high-temperature, precision, endothermic gas generator as shown in Fig. 2 is fully automatic and does not need further adjustment once the proper ratio is set. Many plants are using one large gas generator as a central station to supply atmosphere to all the heat treating furnaces. If an operator desires to cut a furnace in or out of the line, he merely opens or closes the atmosphere valve at the furnace and does not worry about making ratio, pressure, or flow adjustments at the generator; this is all handled by the automatic controls. Where extreme precision is required, the generator will produce an atmosphere to be in equilibrium with any steel from high-carbon to low-carbon, and thus is ideally suited for carbon restoration on decaburized bars, billets or other steel shapes.

Furnace Brazing

Another important development brought about by atmosphere control is the furnace brazing of production parts. The savings and importance of this metallurgical operation were emphasized in World War II when it was found that the capacities of casting and forging shops were not great enough to produce all the ordnance and quartermaster material needed. To meet the required production schedules, items made from metal stampings and screw-machine parts were brazed together to replace a forging, casting, or complicated machine part. This opened the eyes of many manufacturers who saw that furnace-brazed parts were not only cheaper to manufacture but were also lighter and fully strong enough. Today, it is possible not only to furnace braze a part but to also harden it directly from the brazing heat. Roller hearth continuous furnaces represent the standard type now in use.

The development of the machine age to today's high degree of efficiency, power, and speed has been hinged directly on the heat treatment of metal to increase its strength and fatigue limit, at the same time reducing the weight by reducing the cross sections of the part. From the above review of developments in furnace equipment and atmospheres, we can truthfully say the heat treating equipment manufacturers and their technical staffs deserve some considerable share of credit for the high standard of living made possible by American machines of 1947.

Photo by H. L. Millar, Asst. Metallurgist, Plomb Tool Co., Los Angeles



The Quench

A Fundamental Improvement in Temperature Measurement and Control

By Hans W. Bluethe
Advertising Manager
Wheelco Instruments Co.
Chicago

In the first half of the between-war period the perfection of instruments for temperature regulation seemed to be stymied behind the necessity of using complicated mechanical systems between measuring instruments and control valves or switches. This impediment was removed by a Chicago firm in the mid-30's by the invention of an electronic circuit actuated by frictionless movement of a small metal vane in a high-frequency electrical field. Adaptation of this idea to many other control devices has since been widespread.

IF ONE can remember as far back as 1917, when the Chicago branch of the present American Society for Metals was organized, and recall the methods then available for high-temperature measurement and control, he will be struck immediately with the thought that the convenience and adaptability of pyrometry have been vastly improved and its application now extended all but universally. It is well that it is so, for high-temperature measurement and accurate control are absolute essentials to those research activities that extend our fundamental knowledge, and to an increasing extent to the multifarious plants and processes for metal refining, fabrication, treatment and even finishing which apply the principles of scientific control.

In 1917 the fundamentals of pyrometry were well known to physicists and research metallurgists. Thermoelectric couples, using either the platinum metals, the nickel-chromium alloys, or even less noble metals for lower temperatures, were already perfected instruments. Optical, radiation and resistance pyrometers were on the market. The disappearing filament type of optical pyrometer had been proposed and was already available. It is safe to say that the expert could even then make as accurate an observation of temperature, *in the laboratory*, as he can today. The situation regarding the observation and especially the control of temperatures in manufacturing plant processes was entirely different — in the year 1917 pyrometry in the plant was rudimentary in the extreme.

The reason is not far to seek. All practicable methods of measurement depended upon the generation of very small electrical voltages by thermocouples, or very small changes in electrical resistance of the sensing devices. While these small changes could be accurately measured by delicate laboratory equipment, and in fact rugged *indicating* devices were available for plant installation, the problems of *recording* the information and of using the indicator as an automatic device to throw electrical switches or open and shut fuel valves were difficult indeed. Confining our attention to the thermocouple as a sensing device, it will be apparent that the weak currents generated would be no more than sufficient to swing a delicately balanced pointer in front of a scale. To

expect it even to drag a pen across the paper was too much.

The result was that all the recording electrical instruments and control devices of the time included complicated apparatus for making periodic contacts and performing associated motions. They consisted of a multitude of mechanical subassemblies with gears and clamping mechanisms, difficult to operate and maintain. Service had to be performed by experienced engineers or factory personnel. Only the larger manufacturing plants were potential buyers of instruments, while the smaller plants still relied primarily on guesswork and the "educated eye" to control their operations if temperatures were above the range of a mercury thermometer.

This situation existed after World War I, primarily because nothing had been invented to avoid these mechanical complications. Demand was there. The years 1915 to 1918 brought orders from the army, navy and the budding air forces for an almost unlimited output of highly interchangeable parts, the fullest exploitation of resources, and fastest methods of reaching these goals. All these factors brought a theretofore unknown need for instruments to regulate the manufacturing processes and to inspect the manufactured parts. Even so, most of the leading American manufacturers of industrial instrumentation were located in the East. The bulk of the equipment was custom built for the particular application rather than designed as a packaged unit for general use in one line of endeavor.

Charles L. Saunders
Executive Vice-President
Wheelco Instruments Co.

Postwar Impetus

As everyone knows, the technological impetus of the war carried on through the 1920's. Accurate instrumention was needed on all sides, more and more. High speed production actually required it — many operations are entirely too fast for the human's reaction. As the instrument industry expanded to meet these needs many new manufacturers sprang up in the Middle West and several of the eastern companies set up manufacturing facilities in this area.

Wheelco Instruments Co. started as a small laboratory at 1112 Milwaukee Ave. where the Wheeler brothers and a few energetic engineers labored with the problem of adapting electronics to industrial measurement and control. The first models were unbelievably crude; in fact the first sales excursion made by R. A. Schoenfeld, currently a vice-president of the company, consisted of the demonstration of the new model mounted in a cigar box. Despite this humble beginning, far-sighted original equipment manufacturers visualized the revolutionary aspect of this new instrument and their cooperation will always be remembered by men in the Wheelco organization.

We of this Chicago organization date more recent events in relation to 1935, when engineers on our staff made the first successful control instrument with electronic tubes. As it turned out, this principle avoided many of the mechanical complications, mentioned above, that were militating against the wider use of automatic controls. The idea had been discussed elsewhere in a more-or-less perfunctory way, for it was logical that the common use of radio receiving sets should have suggested the idea of multiplying the current and e.m.f. of the thermocouple by a series of electron tubes to where they were strong enough to operate recorders and control mechanisms. However, this direct multiplication idea did not have a commercial application because the required special tubes were not available, and even if available, they would apparently have needed continual checking against a standard circuit — again by mechanically driven contactors.

All these troubles were avoided in the principle first applied by Wheelco's engineers in 1935. The moving needle of the time-tested and accurate

millivoltmeter, actuated directly by current generated at the hot junction of the thermocouple, carried a small metal vane. The arm of the lever which indicated the set point for control carried a pair of coils between which was induced a small current of high frequency by an appropriate external oscillator and circuit. When the temperature measured is at the correct point, the metal vane is exactly centered between these two coils. If the temperature raises or lowers, the metal vane moves to one side or the other. The slightest movement of the vane changes the frequency of the current across the gap between the coils, and this change in frequency, through the medium of electronic tubes, operates to close relays or actuate contacts on any necessary circuits for operating fuel or air valves, proportionate mixers, electric heating circuits, remote recording devices, or warning signals.

The first instruments developed with this electronic circuit were called "Capacitrols", and were used for automatic temperature indication and control. Two of these old-timers are still serving faithfully at the plant of Thurner Heat Treating Co., Milwaukee, Wis. (Fig. 1). Following the initial success many other devices using electronic controls have been perfected by this company. Realizing the exceptional speed of electronic action, most of the leading pyrometer manufacturers have followed the trend, and today electronic instruments are the most popular items in their catalogs. The principle is by no means restricted to thermocouple pyrometry; electronic circuits were quickly adopted for automatic high temperature shutoffs, potentiometer controllers, resistance thermometers, and devices for shutting fuel valves the instant a gas or oil flame snuffs out for any reason whatever.

While electronic controls found a wide acceptance in the metal producing and processing fields where fast and accurate action are an imperative requirement for high-temperature regulation, their use is by no means confined to the metal field. All sorts of chemical and process industries, ceramic kilns, plastic injection and extrusion machines are some of the important users which have brought a large sale throughout American industries.

Looking back on the history of this organization and its relation with the metallurgical industry — and especially with the metallurgical engineers in the Chicago region — we conclude that we were fortunate in being located in the Middle West. Here is a diversified metal industry, and a rapidly growing group of process industries. Chicago is an ideal location for instrument manufacturing. Excellent suppliers of necessary raw materials and assembly parts are located in this area, simplifying procurement and inventory problems. From a modest start on a single floor of an office building, our organization grew rapidly, and today the manufacture of instruments takes all the space in a six-story plant. This history, however, could be duplicated in its essentials in dozens of other spots in this Great Lakes region, where groups of men with sound ideas have built something of importance to all of America.

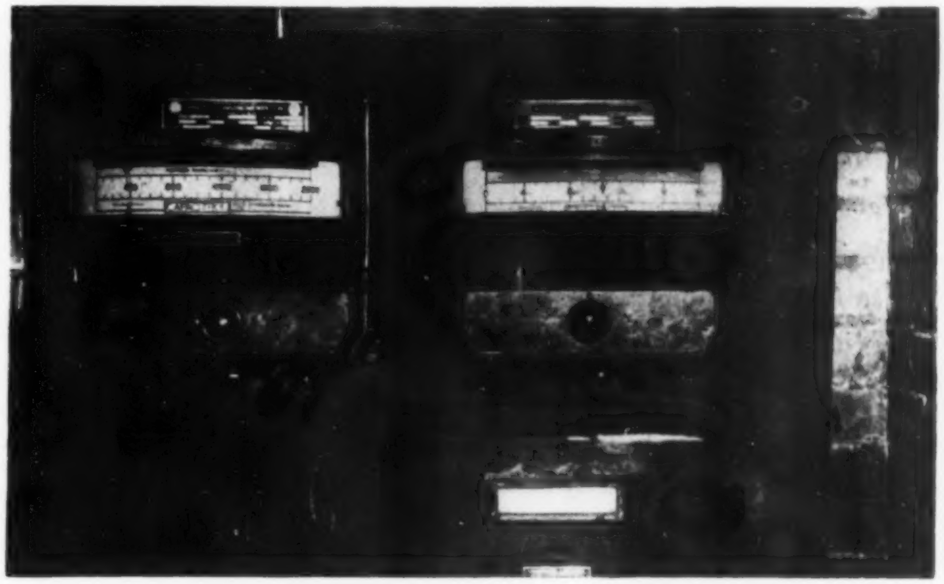


Fig. 1 — Among the First Temperature Controls to Use Electronic Circuits Are These Two Veterans Still in Operation at Thurner Heat Treating Co. in Milwaukee

Today modern instrumentation is within the reach of even the smallest plant and is recognized as an essential requirement wherever production speed, product uniformity, and minimum spoilage are to be attained. It has reached this position because the problems of design, manufacture, interchangeability, and service have been met by the application of engineering principles, and because the level of technical skill in the plants of our customers is continually increasing.

Development of Furnaces With Recirculating Atmospheres

By John Ade
Design and Research Engineer
Stewart Industrial Furnace
Division of Sunbeam Corp.
Chicago

Modern heat treatment of metals, both ferrous and nonferrous, requires many operations much lower than the quenching or forging temperatures for steels where radiation from incandescent brickwork is a satisfactory method of heat transfer. Mr. Ade describes in considerable detail the development of various types of furnaces wherein the hot atmosphere is circulated at speeds on the order of 100 miles per hr., and the most recent improvement wherein this circulation is reversed in direction at fairly frequent intervals.

RECIRCULATING FURNACES are an excellent example of the well-known axiom that necessity is the mother of invention. Their birth occurred as a result of their need in industry, and their development has kept pace with the everlasting demands for improvement.

The earliest *industrial* furnaces were used mainly for heating prior to forging or other hot forming; almost any arrangement of brick and burners would do which would attain the temperatures required. In those days, the few tools which required heat treating were hardened by the blacksmith who made good use of his experienced eye in selecting the proper moment to remove the work from the forge or furnace. After the tool was hardened by quenching, a spot was filed clean and bright. To draw the tool, it was placed in a part of the furnace where the temperature was not too high and where the blacksmith could watch the bright spot change colors and he could again use his experience in judging the right time to remove it from the furnace.

As the quantity of work increased to where the blacksmith could no longer give attention to each tool, it became necessary to adapt the furnace to the job. No great difficulty was encountered in building a satisfactory furnace for hardening by giving the construction details careful attention. The work was fairly uniformly heated, because at the temperatures required (1400 to 1650° F.), the furnace walls, hearth and arch, which were quite incandescent, transmitted most of the heat to the work by radiation. The rate of heat transfer by radiation is very fast at high temperatures, and since a piece of work in an incandescent chamber receives radiant heat from all unobstructed surfaces, such heating is both rapid and uniform.

Tempering, however, presented a real problem. At the lower temperatures needed (400 to 1200° F.) the amount of heat transmitted to the work by radiation was greatly reduced so that most of the heat the work was receiving was by convection — that is, by direct contact with the hot burned gases. Since, at these lower temperatures, there was no increase in the rate of heat transfer by convection, the heating time was made considerably longer. Of perhaps even greater

importance was the requirement of uniformity of temperature throughout the work; unless a direct-fired furnace was of unusually good design and adapted to the particular job, the hot gases flowing over and around the work would heat some portions properly while other portions were still too cold. Such problems were intensified in the heat treatment of aluminum and magnesium alloys, which are heated to comparatively low temperatures, yet these temperatures are quite close to the melting or damaging point.

Recirculating Principle

A correctly designed furnace with the burners, hearth, arch, ports and vents properly shaped, sized and spaced gave results which were satisfactory for many jobs, but wherever mass production or precision heat treating was encountered, the results were far from those desired. At this juncture, the necessity for something new became great enough to create some real activity. It was apparent that very little could be done to increase the amount of *radiation* in the low-temperature range required for tempering steel and solution treating of aluminum. The alternative was to assist *convection* in every way possible.

The Author

The fundamentals of heat transfer by convection were already well known from studies on condensers by power and chemical engineers. The cold body receives its heat from a film of hot gas in contact with it — a film which was physically held to the work. This film then acted to insulate the work from the heat in outer layers of hot gas until it was wiped off and replaced by a fresh hot film. The wiping action — in an industrial furnace — was caused by natural circulation of hot burned gases from the burners to chimney and by draft conditions due to door openings and vents. Anything which would increase the velocity of the gases over the work and thereby speed up the wiping action would increase the rate of heat transfer. First trials were by stirring up the gases in the furnace by paddles and propellers. Results were successful right from the start.

In an effort to reduce costs as well as to improve heating properties, furnace designers next tried the idea of reheating the gases and recirculating them through the furnace. An important problem here was to build a fan which would withstand the high temperatures. Methods of preventing the shaft bearings from overheating were soon developed and — with the use of high-temperature alloys which were available — it was not long before trouble-free fans were built. This made possible the first "recirculating furnace" — or, as it is sometimes called, "forced convection furnace".

In a typical recirculating box-type furnace the burner is in an auxiliary chamber at the end of which is a fan which blows the hot gases into the heating chamber past dampers which spread the flow evenly. After passing through the work, enough gases are vented to make room for hot gases from the burner to replace the heat given up to the work, and the rest passes over to an opening in the combustion chamber near the burner. The mixture of fresh hot gas and recirculated gas is then drawn into the fan, blown through the work chamber and recirculated from work to burner again and again.

Rapid improvements in design have established two important factors in building recirculating furnaces able to handle a large volume of work with a minimum of temperature variation: The first is large fan capacity. This is necessary in order to get the high velocities necessary to take full advantage of the convection principle for rapid, uniform heating. Money spent for bigger fans and motors returns generous dividends and at the same time eliminates a heat treating bottleneck. Modern furnaces have several hundred cycles or changes per minute, developing velocities well over 100 miles per hr. This is especially true of batch-type furnaces where the work is loaded into the furnace in a manner which eliminates any possibility of radiant heating. Only in large furnaces for stress relieving or annealing big castings or welded structures, where the ratio of weight to furnace volume is low and the main consideration is uniform rather than quick heating, can a good job be done with lower velocities.

The second important requirement is an even distribution of flow through the work. There are a number of ways in which the designer can insure this. Dampers or deflectors may be placed just inside the heating chamber in the path of the hot gases, or distribution ducts may be built into the furnace walls so the gases are admitted according to a pattern known to provide uniformity. Still another method is to use a "plenum chamber" where fan and burner cooperate to force hot gases into a chamber (usually under the hearth) and to restrict the openings through and alongside the hearth so that a slight static pressure is built up in the space below and by directing the flow of gases into this space in a manner which converts velocity pressure into static pressure.

L. W. Prestin — General Manager
John Wallerius — Chief Designing Engineer
Sunbeam Stewart Industrial Furnace Division

The static pressure in the plenum chamber forces the gases through the openings in the hearth with fairly uniform distribution. In many batch-type furnaces, such as basket-type recirculating furnaces, the work itself creates the plenum chamber interposing enough resistance to distribute the flow of gases.

There are many other factors of importance in the design of a successful recirculating furnace but they are of primary interest to the designer only, and the two examples given above illustrate the attention required for every detail to insure good results.

Advantages of Recirculating Furnaces

Widespread use of recirculating furnaces on many types of jobs has resulted in the following accepted advantages:

First is the uniformity of temperature throughout the furnace, the length and width of the hearth, as well as through the work.

Second is the speed of heating at relatively low temperatures.

Third is the speed of heating through a considerable depth of work.

Fourth is the ability to maintain low temperatures without difficulty. Since a small amount of hot gas from the burner is mixed with a large volume of somewhat cooler returning gas, the burner can be operated much closer to its full capacity and at a higher temperature than it could in a direct-fired furnace.

Fifth is the wide temperature range through which recirculating furnaces can operate. Unlike direct-fired furnaces (which have rather definite minimum temperatures, depending upon design, construction and maximum temperature), a recirculating furnace can be run steadily and economically at almost any temperature up to its safe maximum.

Sixth is the ability to use oil as a fuel in many circumstances wherein only gas would be practical with direct-fired furnaces. The combustion chamber is much hotter than the furnace proper, and thereby is capable of burning oil while the cooler furnace would cause poor combustion and considerable smoke if direct fired. This is particularly true of furnaces in the 700 to 1100° F. range; oil can sometimes be used in recirculating furnaces at temperatures even below 700°.

Seventh is the greater efficiency due to recirculation. By passing the same hot gases through the work repeatedly and adding only the heat lost during the cycle and the small amount vented, considerable economy is gained.

Eighth is the increased tonnage per furnace. This will range from 30% for car-type and conveyer furnaces to several hundred per cent for batch-type furnaces.

Ninth is the fact that the blower on many gas-fired furnaces may be eliminated, since the recirculating fan pulls in sufficient combustion air at the burner to provide adequate circulation.

Tenth is the elimination of many pieces of combustion, control and safety equipment due to the smaller number of burners on large furnaces. Because the gases all pass through one fan and become thoroughly mixed, it is possible to use as low as one or two burners, even on a fairly large furnace. Also, furnaces operating at temperatures too low to re-ignite a snuffed burner safely require flame-protection equipment at every burner.

Types of Favorite Furnaces

These many advantages have created a demand for many rather unique types of furnaces to fulfill the requirements of specific jobs.

The oven furnace with plenum chamber is the most universal because it can take care of any job by merely sacrificing convenience in handling and the economy resulting from a fully loaded furnace. It has horizontal hearth and door in side-wall. It will do a good job of heat treating anything from a small tool to the largest casting or weldment that can be put through the door, or it will heat a container full of small pieces.

The basket furnace is built for heating large quantities of relatively small parts. This is the pit-type of chamber, work being lowered through the top while cover is swung aside. Drop forgings, castings, stampings or anything else small enough to be most conveniently handled in batches can be heated quickly and uniformly, and the ease with which a whole basket load can be charged or removed gives these furnaces an enormous daily output. For example, a furnace with a 30-in. diameter basket, 36 in. high, can turn out well over 20,000 lb. of steel per day.

Box-type furnaces, in which the heating chamber is more-or-less cubical in shape and entered through a hinged side door, are adaptable to the job where several different sized and shaped pieces must be heated and there are not enough of any one size to fill a basket or a whole furnace, and yet the pieces are most conveniently handled in batches on trays. Parts can be segregated on appropriate trays which are then slid into the frame built into the furnace chamber. Parts requiring longer heating or soaking periods can be left in the furnace as long as necessary. These furnaces are also useful in semicontinuous processes, since trays can be loaded or removed without waiting for a full furnace load, or for parts requiring large shelf area for support.

A recent development is a combination basket-and-box furnace, with a top cover similar to a basket furnace through which either a basket or a frame for holding trays can be loaded and unloaded, and a door on the side similar to a box furnace through which the trays can be handled.

Car-type furnaces are used for heating castings and welded structures which are so large they can be conveniently handled only outside the furnace and away from the heat.

The conveyer furnace is well worth the larger investment wherever the volume of work is great enough and a continuous process is desirable. These furnaces can be used for handling anything from tiny lock washers to locomotive springs; depending upon the parts to be handled and the temperatures involved, the conveyer may be a fine or coarse woven belt, rollers, or chain and plate, or the furnace may be of the pusher type with the hearth and carriers suitably designed.

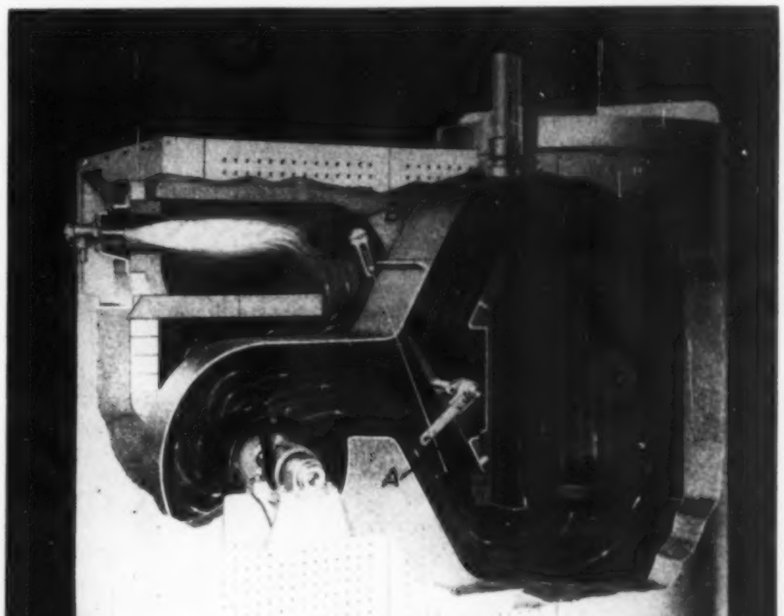


Fig. 4 — Basket-Type of Furnace Wherein Recirculating Gases Are Reversed by Damper A and Motor B on Definite Schedule, Thus Lowering Temperature Differential in Work Load, Top to Bottom, Even in Shorter Than Normal Time

Improvements by Reversed Flow

Research work under way indicates the possibility of notable improvements. A thorough study has been completed of the effect of the work on the recirculating gas itself. It had been recognized for years that fan capacity was of the utmost importance and there has never been any question as to the wisdom of spending the money for the large fans and motors required. However, designers have been of the opinion that there must be other methods of improving the heating characteristics, or that results might be achieved unattainable even with considerably greater fan capacity.

With this in mind, tests were run to learn everything possible about the flow and temperature of the gases through the work, and they clearly indicated that the fastest and most uniform heating was achieved when the temperature drop of the gases through the work was the smallest. In turn, the temperature drop was smallest when the flow of gases took the shortest and straightest path. The greater the number of particles of work with which each particle of gas comes into contact, the cooler the gas becomes, and, therefore, the less heat it can impart to each succeeding particle of work. The greater the amount of turbulence, or stirring action, the more the gas is cooled and the greater the variation of temperature within the work load itself.

Reduction of turbulence to a minimum has resulted in improvement in all types of recirculating furnaces.* However, the tests showed that the parts nearest the *inlet* of the hot gases heated much faster than those near the outlet. This caused an ever-increasing temperature variation through the work until a maximum differential was reached. Then, as the temperature of the parts placed nearest the inlet approached the temperature of the incoming hot gases, more heat remained in the gases as they passed on, resulting in a relatively faster heating rate for the parts near the outlet. This gradually reduced the temperature variation throughout the load to an amount satisfactory for most work at the end of a reasonable heating period. It was readily apparent that if the temperature variation, inlet to outlet, could be substantially reduced, the heating time for many jobs could be shortened, with a resulting increase in furnace capacity.

As long as the hot gases were passed through the work in *one direction* only, there was no apparent possibility of further reducing the temperature variation or the heating time unless the fan was increased out of economic and engineering proportion. However, by reversing the direction of gas flow at frequent intervals, heating rates have been increased and temperature variation reduced. This is not only of great help in arriving at a final desirable minimum temperature variation within the work load, but also is of considerable importance in some types of work where heating rates must not exceed a point which causes more than a permissible maximum temperature variation.

Work heated in a reverse-flow recirculating furnace having the same fan capacity and burner as a conventional recirculating furnace reaches a comparable temperature variation much sooner — or if left in the furnace for the same length of time, will reach a much more uniform final temperature. On one production job where this furnace was given a test to prove its ability to do a real precision heating job, the parts were placed on trays which were piled up to the full depth of the furnace, and the temperature variation was negligible. Thermocouples were placed at seven points in the load of 1080 lb. and after 45 min. of heating time the control couple and all seven test couples read 300° F.

The engraving on the preceding page shows a cut-away view of a basket-type reverse-flow recirculating furnace, designed by Sunbeam Stewart engineers, which shows the reversing mechanism and indicates the path of the gases. By using a single damper installed at the fan outlet to reverse both the inlet and outlet parts of the furnace, a compact, trouble-free design is achieved. The reversing damper is operated by a small motor which is controlled by an adjustable timer to give any reversing cycle desired. Long life is assured for the damper assembly by using the same high quality alloys for its construction that have proven so successful for recirculating fans for many years.

The reverse-flow recirculating furnace described above has passed through the development and testing stages, and it is now ready to prove to industry that progress has not ceased in building better furnaces.

*This conclusion — which is consistent with physical studies of the dynamic flow of fluids through heat interchangers — is surprising to many intelligent furnace users who have thought of the circulating atmosphere as turbulent and the atmosphere in a baffled open-flame furnace as comparatively quiescent, and so have ascribed the advantages of the former to the "turbulence" of the atmosphere.

Nonferrous Metal Industry

Photo by
Margaret Bourke-White
for
Aluminum Co. of America

The Refractory Metal Industry Since 1914

By Allan L. Percy
Manager of Sales Promotion
Fansteel Metallurgical Corp.
North Chicago, Ill.

An important branch of the American industry producing the refractory metals (tungsten, molybdenum, tantalum and columbium) was started in a very small way in the Chicago area almost contemporaneously with the Chicago Chapter, ⊕. Matching the pace of demands by diversified industry, the volume of production — originally weighed in ounces — now is measured in tons.

WHAT does the metal tantalum mean in your life? Not much, probably. But ask any one of some 5000 war veterans who have survived severe head injuries and you'll get a different story. They will tell you that they are alive — healthy and useful citizens — largely because of tantalum plates placed in their skulls by surgeons to replace shattered or missing bone. And the fact that this metal was available to the surgeons is due to a series of metallurgical engineering developments which began back in 1914.

Thirty years ago, when the Chicago Chapter of the ⊕ was an infant, another infant was making metallurgical history in North Chicago. Pfanstiehl Electrical Laboratories, predecessor of Fansteel Metallurgical Corp., in an effort to find a substitute for the platinum vibrator points of the ignition coils, which were then the mainstay of their business, had begun in 1914 to manufacture tungsten. Having mastered the powder metallurgy techniques for tungsten, it was a relatively simple matter to make molybdenum, which was beginning to come into use by 1915.

The refractory metal industry of that day centered largely around Clarence W. Balke, who became Fansteel's director of research in 1916. Dr. Balke probably made his greatest contribution to the industry before coming to Fansteel when, as professor of inorganic chemistry at the University of Illinois, he established a comprehensive program of graduate research in the field of the rare elements and rare earths. After his resignation, his associate, B. S. Hopkins, continued the work, with the result that this department at Illinois has since become one of the world's leading centers of academic work in the study of the rare elements. From this group have come some of the most eminent metallurgists and chemists in the refractory metal field. Nowhere is there a better example of the fact that *men* are paramount to the machine or of the principle underlying the ⊕ that well-informed men are the basis of industrial advance.

The high melting points of the refractory metals make it necessary to use chemical purification and powder metallurgy techniques in their extraction. Because the presence of even small amounts of certain impurities harm their ductility and workability, it is necessary that these metals be made in a high state of purity.

Tungsten is described in every book and many articles on powder metallurgy. Its powder is made by hydrogen reduction of pure tungstic anhydride, WO_3, produced by chemical purification of high-grade concentrates of wolframite (iron and manganese tungstate). The chemical operations and the reduction process must be carefully controlled to produce powder of the desired purity, particle size and particle-size distribution.

The metal molybdenum is made from its oxide by the same general method. Tantalum ores undergo chemical treatments to form a pure double fluoride of tantalum and potassium (K_2TaF_7) which, when electrolyzed, produces tantalum metal powder.

Basic Mechanics and Metallurgy

The real basis of the metallurgy of these refractory metals is the compacting of powders into bars or "ingots", and then heating these bars to the sintering point where the powder particles grow together — yet the metal is not actually

Clarence W. Balke, Emeritus Director of Research at Fansteel Metallurgical Corp., Holds in His Hand a Replica of the First Tantalum "Ingot", $\frac{1}{8}$-In. Square and 2 In. Long, Weighing $8\frac{1}{2}$ G., Produced in 1921. On the table before him is a typical present-day tantalum bar weighing 6000 g.

melted. The compacting of a mass of small, brittle particles under sufficient pressure to make them adhere to each other during removal from the press and subsequent handling is an art in itself. To this problem is added the necessity of equal distribution of pressure so the bars will not overheat locally when sintered.

Sintering consists of passing a heavy electric current through the bar, which serves as a resister — its own heating unit. This is done in special water-cooled furnaces. Tungsten and molybdenum bars are sintered in an atmosphere of hydrogen, while tantalum and columbium are sintered in a vacuum.

After sintering, the metals are rolled, swaged or drawn, and annealed by conventional techniques. Tungsten and molybdenum are worked hot; tantalum and columbium, being more ductile, are worked cold.

The advancement in the science of producing refractory metals during the past 30 years has not involved radical changes in the techniques themselves so much as enlargement of equipment and mechanization and instrumentation of processes. In 1917, for example, the standard tungsten bar, compacted from metal powder, was $\frac{3}{8}$ in. square by 6 in. long, weighing approximately 260 g. (9 oz.). Present-day tungsten bars weigh up to 5500 g. (12 lb.). Chemical processes in 1917 were conducted largely in 10-gal. stoneware jars, stirred with wooden paddles, the materials being carried from one process to the next in pails. Today, the typical tankload of tungstic acid — rubber lined tanks with power driven agitators — is 850 kg. (1875 lb.), and there are usually several tanks working in parallel. Furthermore, except in the laboratory, wet materials are at present never handled manually.

Wartime Acceleration

Such growth and mechanization was not accomplished at one swoop, but through the years, by adding improvements here and there until by 1939 the production of the metals was proceeding at a pace adequate for the industrial requirements of that time. As war threatened, the need for vastly increased quantities became apparent, and plans which had been awaiting greater demands and available capital were put into motion almost overnight. In fact, the plans were revised to take into account the fact that skilled men would be called into the armed forces and replaced by untrained women, and that experience and muscle would have to be replaced by instruments and motor-driven equipment.

For this reason blueprints for a modern plant were laid before the authorities in Washington in the summer of 1941. They were approved early in 1942 and ground for the plant was broken in February; the first shipment was made in Sep-

tember 1942. By the end of the year, the plant, operated by Tantalum Defense Corp., a wholly-owned Fansteel subsidiary, was producing tantalum sheet, rod, wire and fabricated electronic tube parts far beyond its rated capacity — metals vitally needed for radar and a dozen other war equipment programs.

In the meantime, the refractory metal carbide industry was born and had grown to lusty manhood. Tungsten carbide made its first appearance in the United States in 1926, and shortly thereafter Dr. Balke and others in the Fansteel research laboratory were seeking the remedy of a defect in tungsten carbide tools which had become apparent even then. It had already been observed that when steel was being cut with tungsten carbide, the continuous chip from the work dug a cavity or "crater" in the top of the tool, a little back from the cutting edge. When the crater became deep enough, the point of the tool would break off.

After considerable experimenting, it was discovered that tantalum carbide, used as a tool material either alone or in conjunction with tungsten carbide, overcomes this difficulty. This discovery was of fundamental importance, for it widened the field of cemented carbide tools to the whole field of machining of steel. In fact, the same peculiar "self-lubricating" properties imparted by tantalum carbide have been found useful in wire drawing dies and other wear-resisting applications.

Thus, in 1930, Fansteel Metallurgical Corp. introduced tantalum carbide and tantalum-tungsten carbide tools under the trade name "Ramet", and later combined with Vanadium-Alloys Steel Co. to form the Vascoloy-Ramet Corp., now one of the leading producers of tools and other products made of refractory metal carbide. Fansteel has also supplied essential tantalum materials to other carbide manufacturers.

Such a 30-year advance, from the production of ignition parts in a small way, to the tonnage output of the four refractory metals and their carbides, may be regarded (without undue self-gratulation) as illustrative of the metallurgical advances made elsewhere in the Chicago district during the lifetime of the , wherever a sound idea has been promoted by energetic and intelligent men, abreast of the developments in related industry throughout the nation.

Special Triple-Action Hydraulic Press, 3000-Ton Capacity, for Compacting Metal Powders Into Bars of Suitable Size and Form for Sintering and Forging or Rolling Into Commercial Shapes

A Revolution in the Bronze Foundries

By J. D. Zaiser
President
Ampco Metal, Inc.
Milwaukee, Wis.

THE 30 YEARS since 1917 have been evolutionary years for the bronze founding industry of the United States. They have been years of progress, of course; but beyond that they have been years of basic and not too reluctant change on the part of a manufacturing process that once prided itself falsely on being a "craft", beyond the reach of mere scientific study.

One does not have to be very old in the industry to recall sweating workmen laboriously removing gates and risers with hand hacksaws; or the shop boss squinting critically at a crucible of molten metal, judging its temperature without benefit of new-fangled "pyrometer gadgets". The typical 1947 bronze foundry makes quite a different picture, however, and even the old-timers now freely admit the practical advantages of modern equipment.

The Author

While the 30-year evolution in the nonferrous foundry industry has by no means eliminated the small plant casting standard alloys for a local region or for conventional requirements, it has fostered the growth of a few specialized organizations that are equipped to do the difficult jobs for the most exacting uses. Such foundries must lean heavily on technical control; here the metallurgist is no mere luxury but an essential to production.

Traditionally, prior to the early 1920's, brass and bronze foundries were under-capitalized, poorly equipped, and — except for a few master craftsmen in each shop — poorly staffed. Mortality rates of plants and turnover of personnel were high, and in general it was true that the industry as a whole was not highly regarded.

Thus there was plenty of room for the evolution mentioned above; what started as a gradual movement has gained pell-mell headway. As a result, the last decade especially has seen the evolution and growth of a number of large brass and bronze foundry companies serving whole regions rather than just a small locality.

In addition, it is a self-evident fact that the war — with its stringent demands for quality through specification — compelled all branches of the foundry industry to move more rapidly and make the needed improvements in equipment, methods and control more thoroughly than might otherwise have been. Such a movement would have died in its early stages had it not been for the technically trained man. These modern plants give the metallurgist his full due, recognizing that survival depends on sound utilization of modern metallurgical and alloying techniques and controls, and that further growth depends on

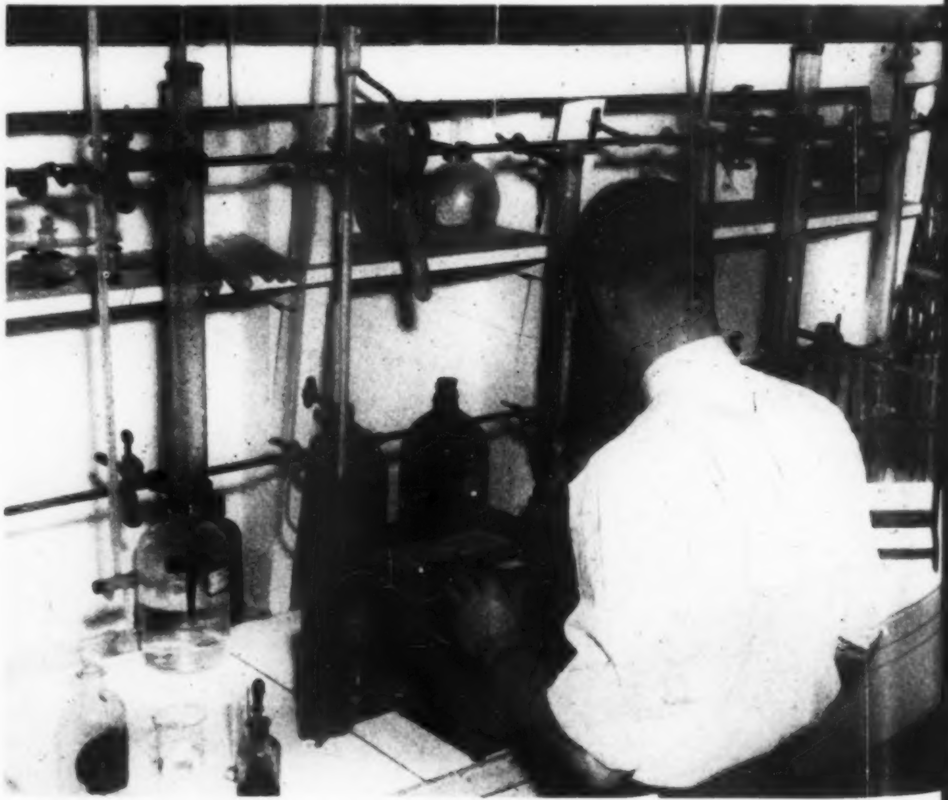
the industry's ability to develop new alloys to meet the technological demands of present-day consuming industries.

The resurgent brass and bronze industry has likewise availed itself of modern manufacturing equipment. Spurred by higher wage rates, greater quantity requirements, and stiff competition, mass-production and labor saving equipment is in heavy demand. Induction furnaces of high or low frequency, indirect-arc electric furnaces, as well as improved gas and oil-fired furnaces, have replaced the old slow coke melting equipment; abrasive cutoff machines are replacing the hand hacksaws of yesteryear; automatic sand handling and reconditioning equipment speeds production and reduces man-hours per unit of production. Technical and scientific control now guides the foundryman, through the use of sand testing equipment, pyrometers, inspection aids, and laboratory control of all stages from alloy composition to microstructure of the product.

When one tries to fix definite dates for the beginning of commercial use of some of these important ideas, he finds it difficult. Using the approximate time of beginning of active marketing as a gage, centrifugal casting of bronze became an accepted procedure about 1930. Precision casting of ornamental bronzes started hundreds of years ago, of course, but the recent revival of the process for mass production dates back only to about 1937. Similarly, copper-base alloys, primarily brasses, have been produced by the extrusion process for many years, but the extrusion of the refractory aluminum bronze and beryllium-copper dates from approximately 1940.

No one who has lived through these revolutionary years can doubt but that one of the foremost contributors to the resurgence of the brass and bronze foundry industry has been the metallurgist. Once classed as an expensive luxury, he has today become a very practical necessity. While it is true that the number of individual foundries with metallurgists on their own staffs is still in the minority of all those specializing in copper-base alloys, these nevertheless are the pacemakers; from such companies stem most of today's new engineering materials, as well as improvements in the older standard alloys. Those organizations whose small size hardly warrants more than rudimentary facilities for control derive considerable benefit from the technical staffs of the large producers of foundry ingot, of which there are a number in the Chicago District. These smaller foundries, while usually unable to contribute new developments, do thus secure at least the basis of the metallurgical control necessary to 1947 manufacturing output. Admittedly, also, it is not absolutely necessary that the plant producing nothing but castings from a few of the standard alloys have full technical facilities. There exists sufficient demand for tonnage output of these long-used and familiar alloys to absorb the output of many such small producers.

The larger concerns are usually those which, in addition to producing standard alloys, also alloy and cast the more difficult bronzes for specialized fields. This type of producer is exemplified by Ampco Metal, Inc., the firm with which the writer is connected and of which he knows



Spectrophotometry — One of the Modern Analytical Techniques Used for Metallurgical Control of Alloys and Undesired Impurities in Bronze

most. As typical of a large copper-base alloy producer and one which has enjoyed unmeasured advantages from its association with progressive metallurgists among the ranks of the American Society for Metals, Ampco's foundry operation may be briefed as follows:

Over 100 different copper-base alloys are regularly produced. Castings are made by any of several processes, including static sand castings and centrifugal castings, in lots of from one to many thousands, and in weights up to 6000 lb. each. Precision plaster castings are also produced to the close tolerances customary with this production method. To handle such a wide variety of exacting work, the plants, both in Milwaukee and Burbank, Calif., are among the most modern in the country, embodying automatic sand handling equipment, conveyerized molding lines, electric furnace melting and the latest type of cleaning and other production facilities.

J. F. Klement
Chief Metallurgist
Ampco Metal, Inc.

It goes without saying that technical and metallurgical control is exercised throughout, including pyrometry, sand conditioning, hardness testing, and constant checking of heat coupons before pouring.

Outstanding among Ampco's controls is the constant verification of metallurgical quality. In production operations, for instance, incoming materials are purchased to carefully written specifications developed in our own laboratory to assure a satisfactory product. All these materials are tested upon receipt before being released to production.

Resultant alloys are checked either through 100% chemical and physical analysis or through similar tests on a generous random sampling, depending on the rigidity of control requirements of a particular alloy. This work is done in the laboratory under the supervision of the chief metallurgist. The laboratory is set up into three separate groups, all working for one end, to wit: a better and less costly product.

The first of these groups is the testing section which acts as a service unit for not only the production departments but also the other two sections of the laboratory. Here all physical and chemical testing is done, as well as the maintenance of control equipment throughout the plant, such as the calibration of pyrometers and hardness testers.

The second laboratory group is devoted to production metallurgy. It is the responsibility of this group to work with the producing departments on problems that arise in alloying, heat treating, fabrication or casting of all alloys in production. This group also works through the sales division on customers' problems. All Ampco standards of quality and metallurgical methods of processing are written and policed by this section.

The third group is the research and development section of the laboratory. It is members of this group who, working first in the laboratory foundry, and subsequently in the production foundry, have developed most of the new products which have become important specialties — even standards — of the company. A few of these include various heat treatments for aluminum bronzes; proper metallographic structure for various specific types of service for aluminum bronze; cast copper with average conductivity of 98% (80 to 85% of pure copper is usually considered acceptable); several new high-conductivity alloys for resistance welding electrode service; a new beryllium-copper alloy of higher physical properties than anything heretofore achieved. In addition, this research and development section also devotes time to studying the extrusion, forging, drawing, and fabrication departments of the Ampco organization.

This same general pattern of operations is being followed in other brass and bronze alloy plants. The contributions thus developed have been the reason for much of the progress in the copper-base foundry industry over the past three decades, and have been accorded due credit for their share in the country's general industrial progress over a like period.

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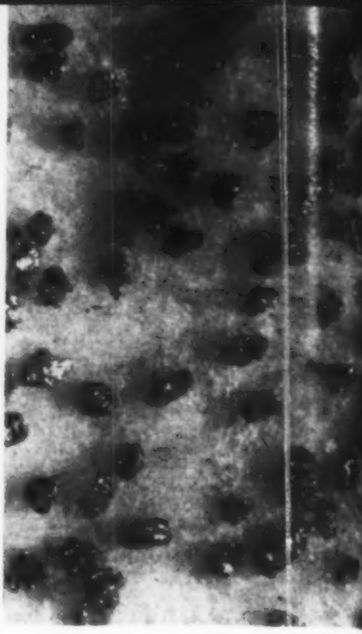

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Impact of Industrial Revolution on Powder Metallurgy

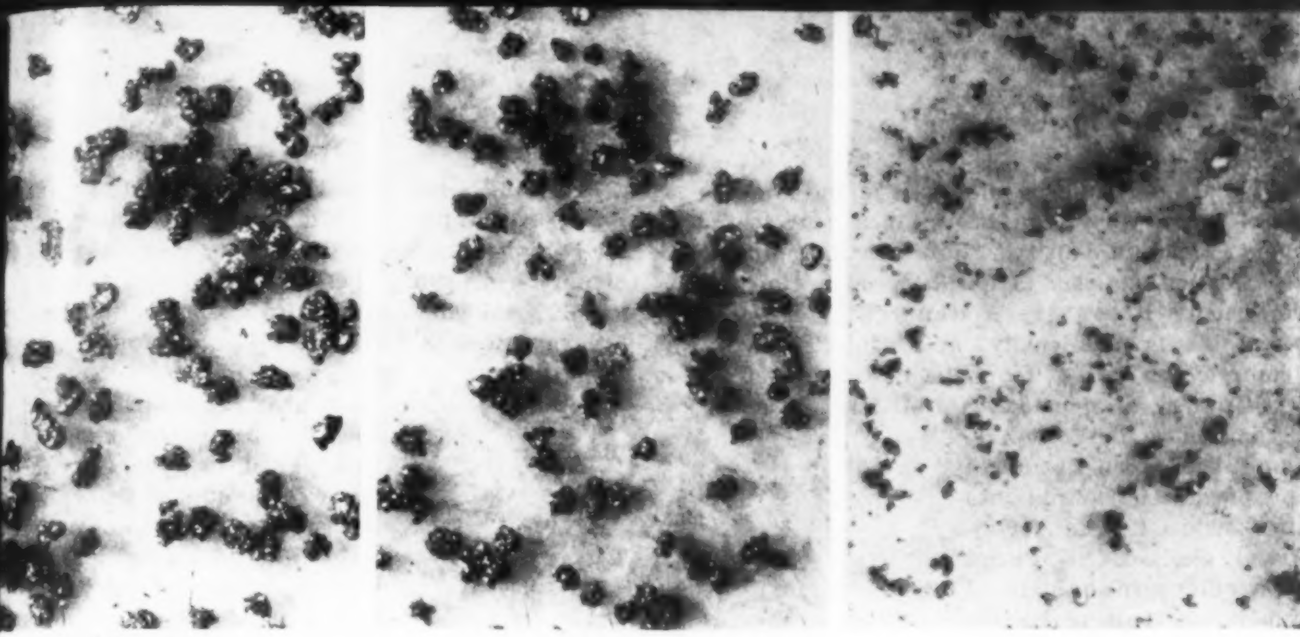
By Joseph E. Drapeau, Jr.
Technical Director
Metals Refining Co.
Hammond, Ind.

THE POWDER METALLURGY BUBBLE will soon burst! It had a glorious but brief life! While it lasted powder metallurgy certainly made the headlines! Claims that it would replace other sound methods of metal fabrication are not holding up! Industrial concerns throughout the nation will lose thousands — millions — of capital invested in these enterprises! Many skilled engineers and metallurgists will be thrown out of work! Trouble is just around the corner!

The above statements would be true only if American industry gave up mass-production methods. Business enterprises in our nation, with their staffs of executives, engineers, and scientific workers, have raised our standard of living through mass-production technology to its present position in the world. American resources have played into the hands of industry in bringing about this phenomenal growth in productivity during the past 30 years. Industries have been constantly seeking improved methods of making products of superior quality at lower cost.

Working of powders of the common metals was dormant in 1917, when Chicago's charter members of what is now the American Society for Metals held their first meeting. In fact, Prof. John Wulff believes the modern art (other than for platinum and tungsten) was ushered in a year previous when, in 1916, Emery G. Gilson of General Electric Co.'s research organization patented a method for making porous, oil-impregnated bearings from copper, tin and lead powders. Why, then, did powder metallurgy take root in the early 1920's after being dormant over 3000 years from the days when the ancient Egyptians discovered that they could reduce iron ore to sponge iron which could be hammered into metallic implements? What place in American economy has powder metallurgy today? What future lies ahead for this unique and novel method of fabricating metal parts?

The methods of powder metallurgy were first



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Photomicrographs at 100 × of Sieve Fractions of a Hydrogen-Reduced Iron Powder

consciously employed in the production of products that were impossible to make by such conventional methods as melting, casting, and machining. For instance, metallic tungsten is produced in a powdered form. The chemically purified tungsten compounds are reduced to metal at temperatures literally thousands of degrees below the melting point. Tungsten powder, when pressed, sintered, and drawn into wire, has a tensile strength of over 500,000 psi. — an example of a strong metal processed from start to finish by powder metallurgy!

Metals with extremely high melting points, such as tungsten, platinum, and tantalum, cannot be obtained directly from their chemical compounds by conventional smelting and refining methods. Here powder metallurgy found its first application. Again, when American engineers and metallurgists were faced with the apparently impossible task of producing porous bearings, combinations of metals and nonmetals such as copper and graphite for electrical brushes, cobalt and tungsten carbide for cutting tools — powder metallurgy techniques solved the problem.

The economic success realized in the fabrication of these unconventional articles that could not be produced by other methods brought powder metallurgy to the headlines. The introduction of mass production and the demand for millions of parts of definite, constant dimensions suggested to engineers and metallurgists that a great variety of machine parts might be so produced. These business ventures have shown that powder metallurgy could eliminate tedious and costly hours of machining, milling, slotting, and grinding.

The industries that pioneered work in the production of parts by powder metallurgy have shown that it offers over conventional methods:

1. Lower cost.
2. Elimination of scrap.
3. Mechanical and metallurgical uniformity of parts.
4. Smoothness of surface and closeness of dimensional tolerances.
5. Shorter tooling-up period.
6. Much higher rate of production.
7. Self-lubricating properties when necessary.
8. Ability to make alloys and parts not possible by other fabricating methods.

Powder metallurgy turns out to be almost ideally adapted to large volume production of many machined parts. A single press can produce from 200 to 1600 parts per hr. Once a new die is designed for a given part, it may be tooled-up in the press in a comparatively short time. The unit cost decreases as the quantity increases; smaller sized parts require a greater volume to pay for the original die cost. There is therefore a place for parts made from powder metals where the volume is in excess of 500 and up to 50,000. On an average, over 50,000 parts can be made from a good die before it needs repair or replacement.

Lest it be assumed that there are no limitations, it should be remarked that there are specific design factors which must be taken into consideration when contemplating a change from a conventional machined part to one made by powder metallurgy. Unfortunately, many parts cannot be produced by powder metallurgy; they do not lend themselves to molding technique.

Nature of the powder and the size distribution of the particles are matters of importance. Typical photomicrographs of iron powder of varied sieve sizes are shown above. Fabricators of powder

metals are particularly interested in the *uniformity* of the powder. One hears much conversation about "apparent density", "flow", "hydrogen loss", and "screen analysis", from the producer of powders, as well as "green density" and "green strength", "sinter density" and "sinter strength", "compression ratios" from the fabricators of sintered parts. Simple tools are all that are needed to determine the compression ratio. Ten grams of the powder is poured into the 0.500-in. hole in a cylindrical die, and squeezed between punches in a tensile testing machine. Changes of dimensions during sintering, determined on this same cylindrical compact, are determined by calipers, gages and density measurements.

"Hydrogen loss" — loss in weight after a definite anneal in a purified hydrogen atmosphere — and carbon content of iron powders are determined by heating in laboratory tube furnaces. These same small tubular furnaces are employed to check sinter-growth characteristics of each blend of powder produced.

Joseph E. Drapeau, Jr.
Technical Director, Metals Refining Co.

Experience has shown that producers of metal powders must adhere to rather rigid specifications to enable their customers to mold a uniform product. Standardization of test methods for powder and finished fabricated parts has been developing rapidly during the past few years. Our industry looks to the Metal Powder Assoc. and the American Society for Testing Materials for standard testing procedures. These two organizations are to be congratulated upon the excellent progress they are making along these lines, so necessary for all producers and consumers of metal powders. These standard test procedures will enable the engineers and metallurgists to talk the same language regarding the powder and the finished parts. They will prove of untold value to America's powder metallurgy development in the days that are ahead of us.

Specifically, in the Chicago area, the company with which the writer has been associated recognized the possibilities that powder metals offered to the large-scale production of metal parts. The company's process has been developed around the hydrogen reduction of metallic oxides. The process is simple: Pure oxides of the metals are ground to controlled particle size and then reduced to metal by heating below the melting point in a flow of pure hydrogen. These reduced metal powders are then milled to break up the sponge-like mass into a powder, and annealed, screened, and blended in 10,000 to 40,000-lb. lots.

When the second world war broke out and the European source of sponge iron failed us, some of the large consumers of iron powder suggested that some of the experienced metal powder producers develop an American source. This was done, and today the producers of iron powder in America are making a product that is superior, chemically and physically, to the European.

Experience has shown that producers must adhere to rigid specifications of purity and physical properties to enable the consumer to mold and sinter uniform products. The ability of metal powder producers to supply their customers with metal powders of uniform molding quality therefore plays a strong role in powder metallurgy's future growth.

Fabricators of metal powders have indicated that millions of man-hours were saved in the United States and some critical delivery dates met in the production of numerous metal parts during World War II. Germany produced and consumed over ten times as great a tonnage of iron powder as we did during the same period. Great quantities were made into driving bands for artillery projectiles — a substitute for scarce copper. Information on the status of German powder metallurgy at the end of the war has been made available through the Office of Technical Service of our Department of Commerce in Washington.

Powder metallurgy can expect startling advances in entirely new types of metal powders in the near future. Naturally, as improved types and quality of metal powders find their way on the American market, we can look forward to broader application of metal powder technique. Where lower costs, closer dimensional tolerances, and a larger volume of articles of the same design are required, American engineers and metallurgists can do no better than to investigate powder metallurgy technique.

Smelting and Refining of Reclaimed Nonferrous Metals

By A. E. St. John
Technical Adviser
Federated Metals Division
American Smelting and Refining Co.

Perhaps in no branch of the metallurgical industry has the impact of technical and scientific knowledge so revolutionized operations as in the reclamation of secondary nonferrous metals. As in the steel industry, a large percentage of the metal entering fabrication shops for conversion into new machines, tools, and utilities is immediately derived from old metal parts that have already served a useful life in some other embodiment, or from circulating plant scrap. Owing to the diversity of commercial nonferrous alloys, the reclamation problem is especially complex; this is shown in the following description of a modern plant in the Chicago region.

"IF IT comes out right, hallelujah; if it doesn't, let's find somebody who wants it!"

That's the way it used to be with the recovery of scrap nonferrous metals. But economic necessity and metallurgical science have long since improved upon the hit-or-miss methods which so often gave rise to these admissions of helplessness. Back in the puppy days of nonferrous reclamation, before the turn of the century, if a fellow happened to be color blind he was at a distinct disadvantage in buying old metal. The distinction between alloys in those days was largely a matter of color, and most copper-base metals fell into either the red brass, yellow brass, or bronze categories. The same loose determination held for babbitts, solders, and other metals. Many a time the value of the specified tin content alone of a solder exceeded the total price of the finished product!

Foundries, as well as scrap smelters, worked on what was largely a guesswork basis, by comparison with today's operations. They turned out many fine castings, however, and in spite of their frequent ignorance of how and why, they got good results.

"Feel" of the metal, its color, its viscosity, were all vital evidence to smelters and to foundrymen in determining the right alloy and the right time to pour it. There might have been as many as 50 different pet formulas in as many different places for what today we know as 85/5/5/5.

Sometimes a silver dime or a brass collar button carelessly dropped into the melt was hailed as the missing link to the formula when perfect castings resulted!

Salvaged metals in general were looked upon with suspicion because people didn't know what they were getting for their money. The buyers didn't have the scientific knowledge and equipment to assay their purchases, and neither did the sellers. Chemical laws of behavior were known in the classroom and elsewhere, but their practical application in the nonferrous refining industry had not yet been utilized.

As a consequence, foundrymen and other

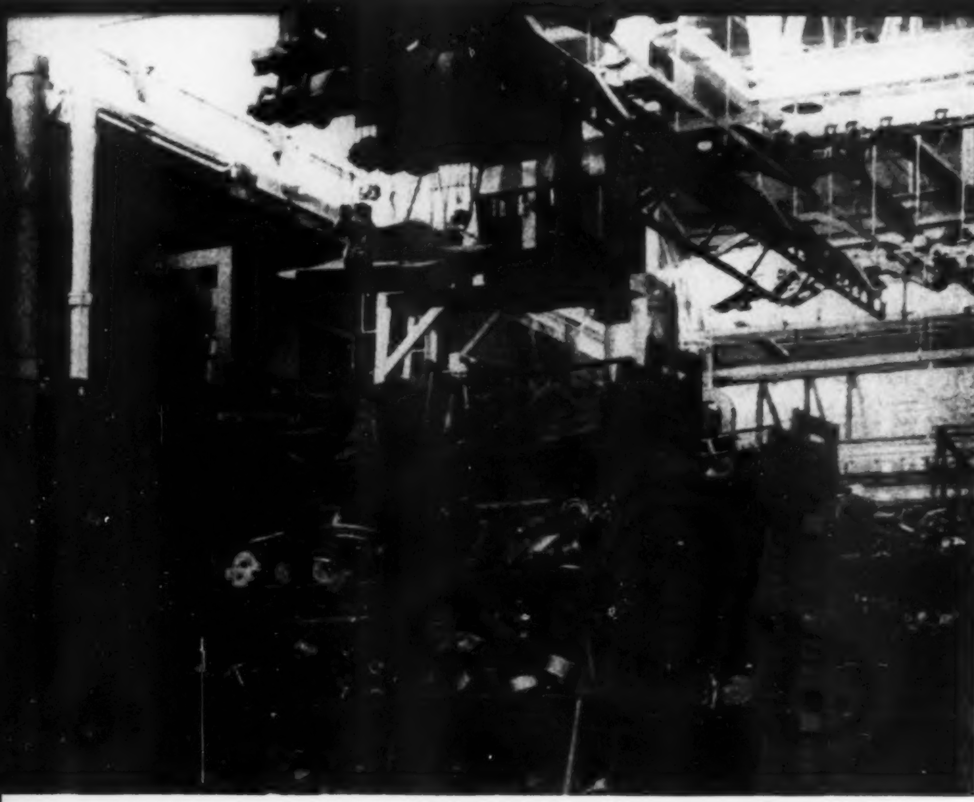

Fig. 1 — Sorted Scrap Is Stored in Metal Skid-Bins; Specialized Crane Transports Load and Dumps Directly Into Furnace

users of nonferrous metals preferred virgin metals, smelted direct from the ores, and generally mixed their own alloys. If something cheaper than virgin material was desired, old trolley wire was a good source of No. 1 copper, beer pipe was a sure thing for tin, and plumbing scrap made a good supply of lead. In the foundry this practice gave rise to the name of "ounce metal" for 85/5/5/5 — one ounce each of tin, lead, and zinc mixed with a pound of copper resulted in approximately the correct alloy.

Some 30 years or so ago the demands of a government at war brought a new interest in secondary metals. The chief result was a step forward toward the rather close specification control which exists today. It suddenly became important to have chemical and physical standards and limits which could be followed by the entire industry.

Accurate analyses and mechanical tests began to play a part. Red brass was no longer just "red brass"; it became apparent that there were many commercial *red* brasses each with individual mechanical performances. Impurities were recognized; their effects were studied; methods for elimination perfected.

Various engineering societies established committees to coordinate and disseminate data. They set up standards of composition and performance which helped change what had been haphazard, dissociated efforts into a well-organized industry reclaiming secondary metals. It was a logical matter for American Smelting and Refining Co., one of the world's leading interests in the virgin metals field, operating large ore smelters at several mining centers in North and South America, to associate itself with this movement, as did its competitors. In its long history of some 70 years had been gained an important store of skill and information about the purification and refining of such metals as copper, lead and zinc, and the treatment of residues, fume, skimmings and "ashes" for their valuable byproducts of rarer or precious metals. A. S. & R. Co. therefore gave generously of these resources of practical experience; the firm also invested over $10,000,000 in refining plant operations throughout the country, plants especially constructed for the reclamation and treatment of demolition scrap and returns from machine shops using the nonferrous metals.

However, by today's yardstick, efficiency was still at a pretty low level. Few trained metallurgists were employed and little scientific equipment was used for research, on-the-job analysis, and general quality control.

Handling of materials was done largely by manpower and this gave rise to considerable time and money loss. Scrap generally arrived at the refinery by truck or wagon, was unloaded by hand or shovel, and moved inside by wheelbarrow or pushcart. It was then dumped in piles, sorted piece by piece, and shoveled into bins. The shovel, fork and wheelbarrow were used again whenever scrap had to be moved.

Furnaces were small and inefficient. Crucible pit furnaces were common, and the operation consisted in remelting rather than smelting and refining. The product was accordingly far from uniform. A carload of metal contained ingots from many heats which were mixed and sampled as one lot. Babbitt metals were either "high grade" or "low grade", depending on the tin content; "half-and-half" solder might have contained anywhere from 35 to 50% tin. (Aluminum alloys were hardly known at that time; it is only recently that their recovery became of importance.)

During the past 30 years, continuous study in the laboratories and in the field has shown that aluminum, brasses, bronzes, babbitts, solders, type metals, and other nonferrous metals and alloys can be used again and again, the only limit arising from the economics of collection and reworking.

Thus the bugaboo about the inferior value of "second-hand metals" has vanished.

Engineering Acceptance of Reclaimed Ingot

It was proved that the only criteria necessary to judge the value of a metal or alloy are its composition and properties. The *source* of the raw material is not important. Copper is copper no matter whether yesterday it was a molecule in chalcopyrite down deep in a mine or mixed with zinc in a bathroom faucet. This fact has long been uncontested in the steel industry which gains about half of its new ingot weight from scrap — salvaged iron and steel.

This increased acceptance of reclaimed metals as perfectly satisfactory engineering materials is due largely to the science of the metallurgist and chemist. In this general educational process the Chicago Chapter of the ⊛ takes a leading position.

The methods used by secondary smelters are highly specialized and the users of refined alloys have benefited because scientific methods for segregating various types of alloys have been applied; the effect of furnace atmospheres on metal quality has been studied; harmful oxide inclusions and absorbed gases have been eliminated; undesirable impurities have been recognized, isolated, and means discovered to get rid of them; the effect of minor elements on properties has been investigated thoroughly. All of this results in better metals to do more jobs better.

It is interesting to note that although the theoretical aspects of these controlling procedures have long been known and are largely the same as they were in the past, the *mechanics* of the operations have been so improved that the result can now be predicted with reasonable certainty.

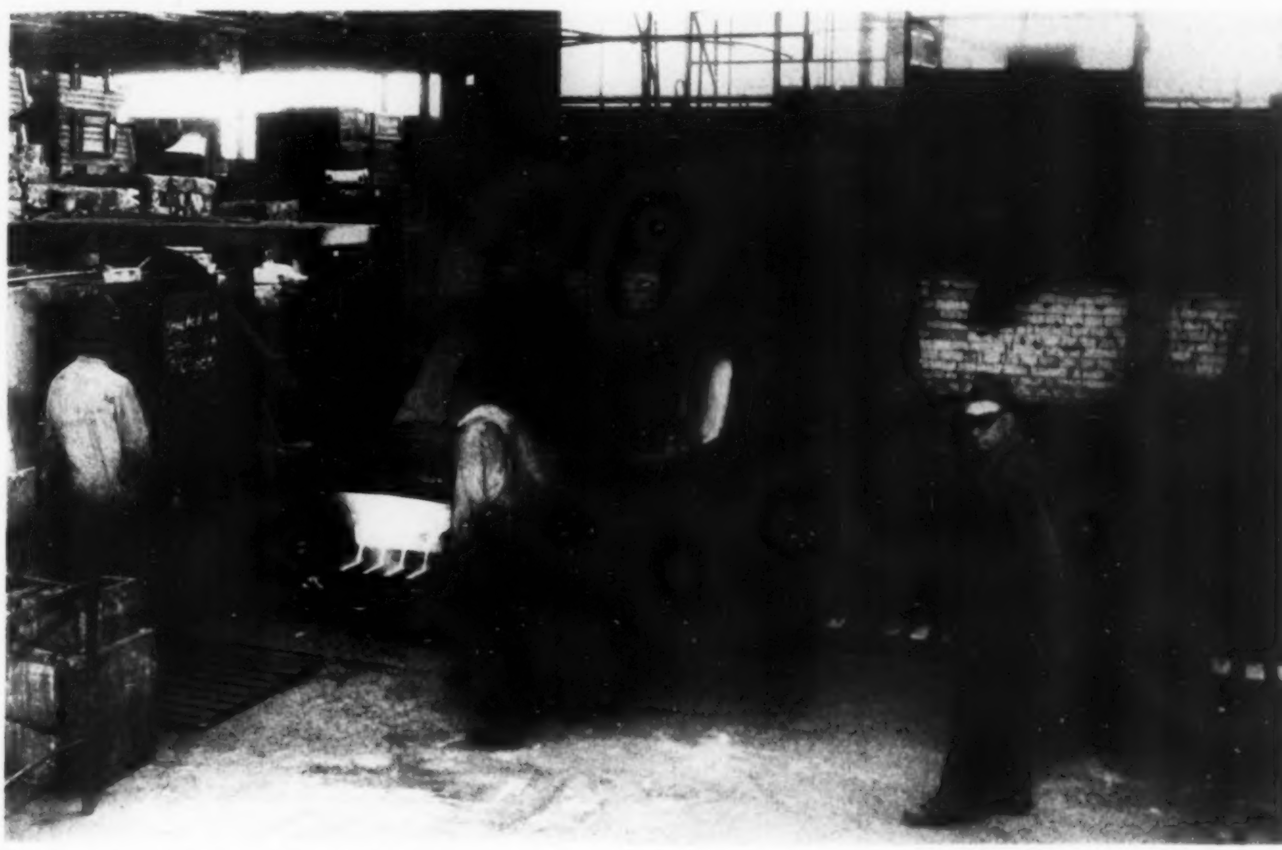

Fig. 2 — Fifty Tons of Brass (Reclaimed Metal, Held Within Narrow Chemical Tolerances of Modern Engineering Specifications) Being Cast Four Ingots at a Time Into Molds on Traveling Conveyer

Besides the rapid progress that has taken place on the metallurgical side of the industry, many other improvements have also been made. Health and safety hazards are fought continuously; handling of materials is done almost exclusively by automatic conveyers, industrial trucks, and overhead cranes; furnaces for copper-base alloys have increased in size and may hold as much as 200,000 lb., while aluminum furnaces may have a capacity of as much as 100,000 lb.

Furnace sizes in the smelting and refining of white metals have progressed in the same direction. The tendency in the industry today is to make the heats as large as possible so that greater uniformity can be maintained, and production costs and selling price can be reduced.

Photographs in the old Chicago plant of Federated Metals Division of American Smelting & Refining Co., when compared with views in the new (1939) plant in Whiting, emphasize these revolutionary changes in equipment. In the one was back-breaking manhandling, crucible pots, small reverberatory furnaces, smoke, rule-of-thumb. In the other is most modern materials handling, large melting units, adequate conveyers, exhaust systems and fume recovery, chemical control. As in other lines of industrial activity, the demands of World War II for unprecedented quantity and quality production played a necessarily vital role in speeding up this progress.

Fig. 3 — Ingots, Bars and Sticks of Finished Alloys in Warehouse. Pallet boards, skids, skid-bins and monorail system save labor and prevent mix-ups

Incoming material is now received by truck or rail at unloading docks capable of handling many arrivals at one time and thousands of tons yearly. It is then moved by any of a variety of industrial transportation systems to the sorting department where it is classified as to alloy composition and grade. After this, each lot or bin-load is further sampled and analyzed by rapid chemical methods. This elaborate system of classification permits the best use of metal from both metallurgical and economical standpoints.

Materials which do not lend themselves to mechanical sorting, such as residues, drosses, and battery plates, are remixed, sampled directly and assayed, lot by lot.

After the metals are sorted, they are removed to storage, where they are kept in steel containers or skid bins so designed that they can be handled by one man, either with an industrial truck or an overhead crane. Much of the equipment — like that shown in Fig. 1 — is such that the crane operator can discharge the contents of the skid bin directly into the furnace.

Chemistry and Metallurgy Is the Key

The key to all operations in the industry is chemical-metallurgical. Here is where the greatest progress has taken place since the infancy of the industry. The improvement in quality and the increased usefulness of the industry's products are tied up with the advances in this technical department.

In the laboratory, constant checks are made on materials — when they are purchased, before they go into the furnace, while they are in the furnace, and after they come out of the furnace. Here the latest methods and equipment are employed to their fullest efficiency. Here we find not only the usual quantitative chemical equipment, but also the latest spectrographs, spectrophotometers, and polarographs.

Likewise the importance of the trained metallurgist in the industry cannot be overemphasized. Large organizations, like Federated Metals, have recognized this fact in staffing their key positions with technically trained men. Long-range planning, such as is also done by this company, in interviewing and hiring graduates at outstanding colleges, in opening their plants to student field trips which supplement their regular courses, and in distributing educational literature in schools, will insure the nonferrous metals industry of a continuous flow of scientifically trained men, and will assure the users of these nonferrous metals quality that is continuously improving — worthy engineering materials.

Photo by Crane Co.

Metallurgical Progress

in plants of

Representative Chicago Manufacturers

Examples of Metallurgical Progress at International Harvester Co.

By Members of the Metallurgical Staff*
International Harvester Co.
Chicago

In this issue of Metal Progress commemorating 30 years of service to industry by the Chicago Chapter, ⊕, the cooperation of International Harvester Co. was enlisted to show how advances in heat treatment have been utilized in improving a product whose influence is world wide. Examples were so numerous it was difficult to fix upon the most representative. Induction hardening of surfaces, continuous bright hardening of parts finished except for final grind, short-cycle (14½ hr.) malleable iron, are instances wherein this organization is either the pioneer or an exemplar of modern practice.

BECAUSE of the division of labor in modern society it is no longer necessary for every man to be a tiller of the soil to sustain life. A fraction of society with modern farm machinery can produce the food supply — but this fact serves to high-light the interdependence of all people in modern society. Of the extractive industries, which are basic to the entire productive process, agriculture is first in economic importance. Man can exist (in a state of savagery, it is true) without coal and iron and oil; he can sustain life, conceivably, in certain climates without fibers or wood. He cannot live without food. Only in a few areas does Nature provide all the food necessary, unasked, and these regions could support only a small part of the world's population.

American agriculture today supplies almost all the raw food materials and fibers that are used to sustain and clothe the whole population — with only a fraction, relatively, of the numbers engaged in producing the raw materials for these needs in earlier generations. This development is a great credit to agriculture, for it has released a great number of people to develop the other great industries that have raised the American standard of living to its present levels.

The problem of the farmer under any economic system is to produce as efficiently, as unfailingly, and as easily as possible. The business of the farm equipment industry, of which the International Harvester Co. is a part, is to improve the farmer's ability to do that. The farm tractor, more than any other force, has brought an industrial revolution to the farmer and his farm, substituting mechanical power for animal power. Today there are almost three million tractors on farms in the United States.

Many manufacturing organizations have contributed to the development of the tractor. Count-

*Those cooperating in the production of this article include:

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G. P. Phillips, chief metallurgist, automotive foundries;

W. D. McMillan, chief metallurgist, implement foundries;

A. S. Jameson, assistant supervisor, metallurgy, manufacturing research laboratories;

N. T. Nilson, chief metallurgist, industrial power division;

R. F. Pinter, works metallurgist, Tractor Works, industrial power division.

les individuals have furthered its design and development. No group can be given all the credit, but the influence of the metallurgists has been as important as that of any other.

Commercial production of tractors powered by gasoline engines may be said to have begun in the first decade of the present century. Before World War I their use was widespread; during that war it greatly increased. However, at the war's close the agricultural tractor and power farming were still in their infancy. The tractor was a homely brat, large for its age, that snorted lustily at any assigned task, and yet outperformed the faithful horse, the stubborn mule, and its own godfather, the steam traction engine.

The first tractors and harvesting machines were designed for the large farms. At the present time there is a demand for different types of power farming equipment, in sizes suitable for every farm from less than 40 to more than 1000 acres.

Important Metallurgical Problems

Not much attention was given to the materials that went into the first tractors — a few time-honored steels, iron castings, babbitt bearings. Since then a great deal of thought has been given to metallurgy — as of course would be necessary before farm machines could be mass-produced which would have long life and give the farmer the maximum performance at the minimum cost of both equipment and operation. This has depended upon the selection of the proper grade of steel, iron, or other materials, and heat treatment to produce the best combination of hardness, strength and toughness.

In some ways the tractor problems have been more difficult than anything encountered in the automobile industry. It is not uncommon to operate hour after hour in low gear at almost full motor torque. If the reader will consider how many minutes during his entire driving experience he has operated a car in first gear with the motor straining to the limit, he will realize the difference in the severity of automobile and tractor service.

Track-laying or crawler tractors have also brought new types of metallurgical problems. This type of tractor is invaluable for certain farming operations, and for many industrial and constructional tasks, but the building of a satisfactory track chain has taxed the metallurgist's skill to the limit. It must withstand the jolts and bangs of travel over a rocky terrain. Furthermore, it is the only known piece of machinery which is lubricated with sand and water! Heat treatment of track shoes and links would be worthy of an article by itself.

Then came the small diesel engine — a powerful brute, very economical in operation. As this is inherently a high-compression engine, maximum strength and wear resistance of component parts become of extreme importance.

How some of the problems involved in the production of durable and economical equipment have been solved is explained in more detail below. For the present, suffice it to say that induction hardening of crankshafts and track chain pins has greatly increased their life. Similarly the development of heat treated alloy iron cylinder sleeves has increased their wear resistance 500%.

The introduction of engine power on the farm has meant more severe operating conditions for all types of farm machinery and tools, and it has been the job of the metallurgist to improve the quality of the entire line to meet the more severe demands of power farming and at a reduced cost to the purchaser, if at all possible. He has therefore been vitally concerned with the study of casting, forging, heat treating, welding — in fact, *all* types of manufacturing operations. It is a fundamental principle that the customer, in this case the farmer, is given the best service only when he is supplied with a high-quality durable product at the lowest final cost.

As the Harvester company has been one of the leaders in the creation of power farming equipment, it has been necessary to pioneer the study of materials and processes required to build satisfactory equipment economically. A great deal of time has been given to the laboratory study of the performance of critical parts, and to a scientific investigation of all types of manufacturing methods.

R. E. McGee
Supervisor of Metallurgy
(Manufacturing)

Ferrous metallurgy in the International Harvester Co. is unique in that it starts with the smelting of iron ore, refining of steel, and its fabrication is carried on in many engineering and manufacturing departments. Both the latter are vitally concerned with metallurgical research and development. Both consider the quality and the durability of the product as the first and most important consideration. The importance of cost is second only to that of quality. Minimum production cost consistent with satisfactory quality means giving the maximum service to the user.

The metallurgists are primarily interested in the study of the performance of various parts and assemblies, the determination of the stresses encountered, the selection of the best type of material, and the best range of physical properties for each class of part such as gears, axles, shafts, or blades used in trucks, tractors, and implements. They are an essential factor in achieving the Harvester goal of large-scale production of quality products at lowest possible cost.

Metallurgists are also entrusted with the quality of the product during processing; it is their duty not only to protect the quality but also to aid in reducing cost, improving the efficiency of the operations by new materials, new ideas, and new methods of processing.

Advancement in the quality of product has been made gradually, with experimentation and research at every step along the way. Much pioneering work in the development of practical applications of the various processes has been carried out by Harvester metallurgists. The book is still incomplete, however, for refinements and new uses of the various innovations are continuous and never at an end. To insure that the metallurgical aspects are not overlooked, Harvester's recently established manufacturing research department will devote a large share of its facilities to metallurgical research laboratories.

So much for the generalities. So far we have tried to sketch the importance of the farm machinery industry and the importance of the metallurgist to that industry. Let us now turn to a more specific description of a few innovations and new procedures, selected from several times as many possible examples.

Induction Heating

ONE of the most important factors in the advancement of tractor metallurgy has been induction heating for the treating of numerous parts. Where its use has been feasible we have been able to harden steel parts selectively with the desired hardness and correct hardening pattern. This has been accompanied by *(a)* replacement of expensive alloy by plain carbon steel; *(b)* reduction in time of operation; *(c)* reduction in fuel (heat) requirements by selective heating; *(d)* reduction in floor space requirements by placing equipment directly in production line, thereby effecting savings in handling; *(e)* elimination of some carburizing operations by substituting medium carbon steels inductively heated for carburizing grade — this in turn eliminates copper plating where soft cores are required and reduces or eliminates cleaning operations; *(f)* reduction of distortion, thereby reducing straightening operations, allowing closer tolerances prior to treatment, and subsequently removing less stock after hardening with a resulting decrease in time of finish machining operations, grinding or lapping; *(g)* lessening the tendency for decarburization due to short-cycle heating; and *(h)* lessening the tendency for scale formation. Truly this is an impressive list of advantages.

International Harvester Co. was the first in industry to install and use this type of equipment commercially for the treatment of various production parts, operating its first machine for hardening of pins and bearings on diesel and "F-12" tractor crankshafts in 1936. This equipment was the outgrowth of an extensive program of development by the Ohio Crankshaft Co.

Since that time great strides have been made in the development of this type of equipment in audio frequency (low cycle) and radio frequency (high cycle). In addition to crankshafts, Harvester is now induction treating such items as camshafts, bull gears and miscellaneous gears, track rollers, track link pins, as well as numerous miscellaneous parts. Among other things this heating process is also used in soldering of radiators and brazing of tools as well as selective annealing or tempering of thread ends. A number of low-power (15-kw.) machines have been installed for silver brazing assemblies of sheet metal stampings — formerly either cast or welded parts. Harvester pioneered the use of the high-pressure oil spray quench combined with induction heating on steels which had previously been water hardened. High frequency equipment for heating forging billets is now being installed at one of the company's works.

It is not the intention to convey the idea that induction heating is a cure-all, as there are some

limitations to its use. It has satisfactorily replaced a number of carburized parts; others are constantly being studied for further replacement. The same applies to other types of heat treated parts. As yet the majority of hard surfaced parts, as well as other types, are still being heat treated in the conventional manner. However, the possibilities of induction hardening are still enormous. Its future can hardly be predicted, especially for selectively treated parts or those otherwise difficult to heat.

The installation of induction heating equipment has also played its part in promoting uniformity of control and quality of products with, in many cases, a production increase or a reduced cost.

In the following descriptions of typical installations, a comparison is made with the former method of treatment, and the advantages obtained in the way of improved product, or a reduction of cost, or both, have been listed.

Hardening Crankshaft Bearings

Old Method	Induction Method
Material: 3140 or 4140 Selected Requirement Quality.	Material: 1046 (restrictive requirements) induction quality.
1. Forge.	1. Forge.
2. Restrike after trimming off flash.	2. Normalize at 1700 in pusher furnace and hot coin in a 250-ton hydraulic press. Air blast in a six-station cooling chamber to a minimum Brinell hardness of 207.
3. Normalize at 1700 in pusher furnace.	3. Clean.
4. Cool in still air on conveyer.	4. Machine.
5. Heat to 1550 in rotary furnace and time quench in water in quench fixture to hold distortion to a minimum.	5. Induction harden.
6. Draw at 900 to 1000 to a specified hardness of 239 to 341 Brinell.	6. Draw at 460 for strain relief.
7. Straighten immediately from draw heat.	7. Magnaflux and test for hardness (file hard).
8. Pickle twice to remove all heat treatment scale.	8. Finish grind.
9. Machine complete, allowing grinding stock.	9. Inspect.
10. Finish grind.	
11. Inspect.	

Crankshafts — The first Harvester use for induction heating was on crankshafts, the purpose being to increase wear resistance of crankpins and to obtain a longer life. Outlined below is a comparison of the old method (in which the crankshafts were S.A.E. 3140 and 4140 alloy steel) with the induction method using plain carbon C1046.

The disadvantages of the old method were excessive distortion, bad balance, and pins out of plane. To obtain proper balance it was also necessary to allow considerable over-all stock for machining. An unusual amount of straightening was also necessary after heat treating — and often after machining.

The adoption of the induction heating method, in addition to eliminating the necessity for alloy steel, gave the following pronounced advantages:

Restrike operation at forge hammer was eliminated. Crankshafts were straightened in the die during coining operation to conform to true plane of cheeks and pins, thus maintaining a close tolerance in all dimensions; as a result no further straightening is necessary. Strains were eliminated and uniform balancing obtained without cutting away large portions of the cheeks. Machining costs were considerably reduced. Due to file-hard surface, increased life was obtained on crankpins and field failures were greatly reduced.

Track Link Pins — Track link pins of various sizes (Fig. 1) were formerly made from S.A.E. 1015 (restrictive requirements). Much stock had to be allowed for grinding and straightening oper-

Fig. 1 — Track Link Pins, 6¼ x 1⅜ In. Diameter, Sectioned Longitudinally. Note uniformity of hardened surface zone. Hardening done end-to-end, continuously, at 33 in. per min. during passage through an inductor ring and a quenching ring immediately below it

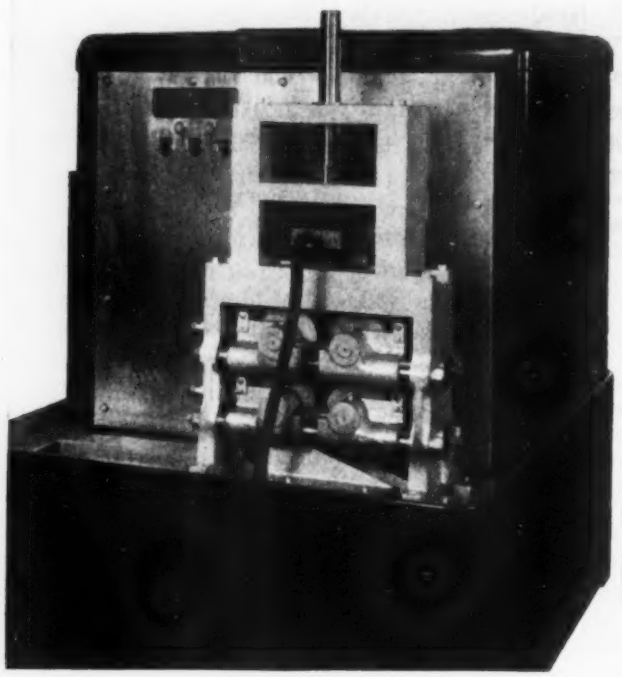


Fig. 2 — Continuous Hardening Machine for Track Link Pins. Vertical drop through inductor and quench rings is controlled by double pair of rollers

ations. The following is an outline of the procedure followed:

1. Cut bar stock to length.
2. Carburize to a case depth of 0.070 to 0.080 and slow cool in box.
3. Truck to hardening furnace and quench from rotary furnace in brine; draw.
4. Clean (Wheelabrator).
5. Inspect for hardness.
6. Grind.

For the present method (induction hardening), Harvester uses a special C1046 killed steel, turned and polished to 0.002-in. limit. Procedure is as follows:

1. Cut bar stock to length. (Operation is located adjacent to the hardening unit, thereby eliminating trucking.)
2. Pins hardened by induction to a depth of $\frac{1}{8}$ to $\frac{3}{16}$ in. Hardness: Rockwell C-60 to 66, or file hard; C-50 at depth of $\frac{1}{8}$ in.
3. Centerless grind.

The hardening process is continuous (Fig. 2). The heating block is a copper ring about $\frac{3}{16}$ in. larger than the pins, and about 1 in. below is a spray ring. The pins pass, one following another, end to end, through the rings during a governed time cycle, thus heating and quenching continuously. Production varies from 5030 pieces per hr. of the small "T-6" pin to 2784 per hr. of the large "T-18" pin, averaging 4230 pieces per hr. for all types in an 8-hr. shift. Residual heat is left in the pins, eliminating necessity for drawing operation.

By changing to induction heating the following advantages and savings were achieved: Elimination of trucking; cutting down floor space for hardening from 780 to 80 sq.ft.; handling operations cut from six to two; carburizing and hardening eliminated with a great savings of time; cleaning and straightening eliminated.

Track Rollers — Because of their design, track rollers must first be rough machined and then heat treated all over to a hardness which would permit subsequent machining operations — not in excess of about Rockwell C-42. It would have been prohibitive from a cost standpoint to carburize and harden. When selective induction heating was substituted a much improved product was obtained and at the same time the cost of operation was reduced.

By the introduction of induction heating, a part that did not lend itself to proper treatment and required an expensive treatment was transformed by a simple and speedy operation. The new method allowed the complete machining of bore and inner races after hardening, thus insuring that parts could be brought to definite size and made into definite assemblies. Field changes could be made positive with no fitting required. Field complaints are now practically unheard of. Total time required for heating each roller run during the induction process is 90 sec. (3 min. for the complete cycle) as compared to approximately 5 hr. for hardening and drawing in furnaces by the former method.

Radiator Soldering — Harvester's previous method of soldering radiators was strictly a hand operation and much depended upon the individual

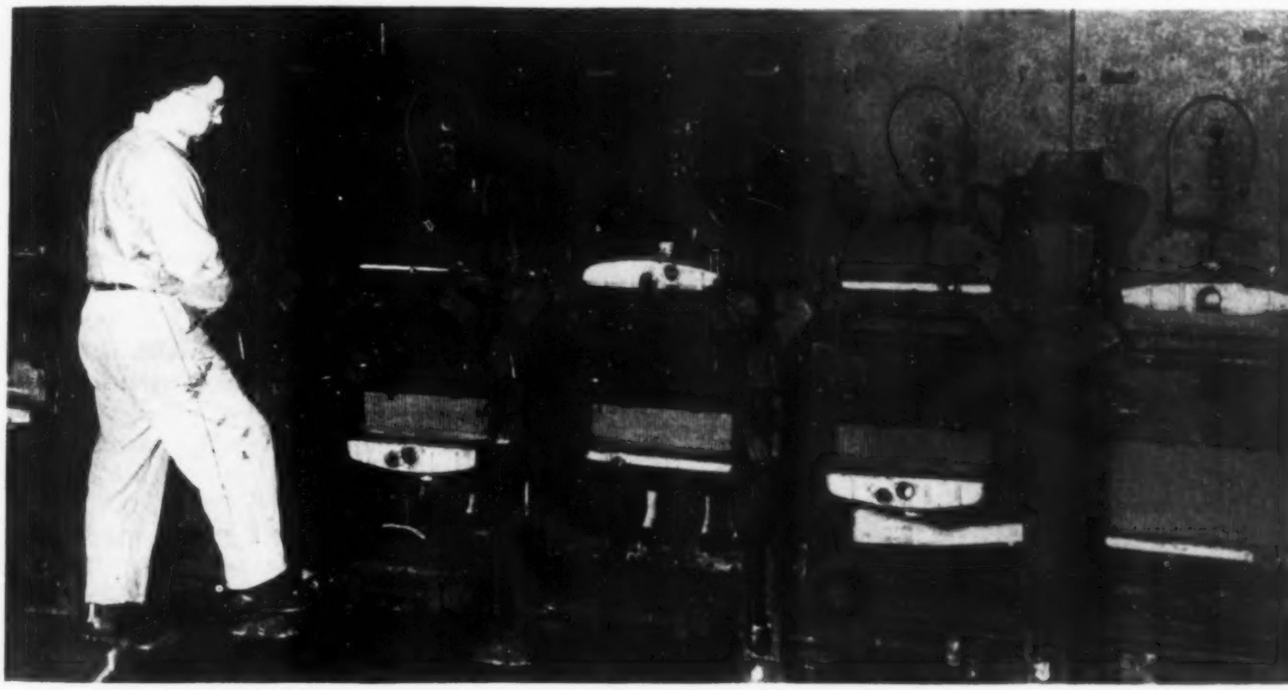
Hardening of Track Rollers

Former Method	Present Method
Material: S.A.E. 1040. 1. Forge halves. 2. Weld halves together. 3. Normalize. 4. Rough machine. 5. Harden. 6. Draw. 7. Finish machine complete.	Material C1043, killed, fine grain (special requirements). 1. Forge halves. 2. Weld halves together. 3. Normalize. 4. Machine runner and flange. 5. Induction harden runner and flange to Rockwell C-55 to 60. Residual heat is left in the rollers and draws them. 6. Complete machining of bore and inner races after induction heating.

workman. Flowing solder with an iron did not always create a good bond and the operation called for highly skilled men. Production rate per operator was low, amounting to only ten radiators per hour. Faced with increased production schedules and with a minimum of floor space available, one of our works, in cooperation with a supplier, engineered the six-station work unit shown in Fig. 3 which — together with a 20-kw. induction heating machine — solved the problem. One man is now able to produce 28 assemblies per hour. Preformed wire rings, containing the proper amount of solder for a joint, are used.

Soldering the upper water tank to the radiator tubes is done in one station and the bottom tank is attached in the adjacent station. In the first operation the entire radiator head is placed in a split coil of the hinged type and locked in place. The pre-formed solder ring is laid in the crimped edge, fluxed, and heat is induced at the outer edges, heating the brass until the solder melts and flows into all joints, thus creating a positive bond. The heat cycle is approximately 30 sec. The radiator is then removed, inverted, placed in second station where the operation is repeated for the lower tank. One man operates one pair of machines; the three pairs of machines are set up for three radiator sizes.

Fig. 3 — Six-Station Unit (Three Pairs for Three Radiator Sizes) for Soldering Top and Bottom Water Tanks to Radiator Tube Assembly



Continuous Heat Treatment of Ball Bearing Race Rings

BALL BEARINGS in the power transmissions of International Harvester trucks and tractors have greatly increased their efficiency. Today, ball bearings are being applied to farm implements extensively, and the farmer will get more from these machines. Higher loads and speeds have resulted in an increased demand for high-quality ball bearings.

In 1944, Harvester completed an entirely new ball bearing manufacturing unit, incorporating the most up-to-date ideas in handling and fabrication, to meet this demand at the lowest possible cost. Within this unit a newer approach to the heat treatment of ball bearing race rings was developed — that of tying in heat treatment to the synchronized conveyer system of the other manufacturing operations. The benefits of such integrated manufacture are too well recognized to require elaboration. Suffice to say that lower cost and more uniform quality control resulted.

Formerly, the practice was to truck the machined parts to a separate building devoted

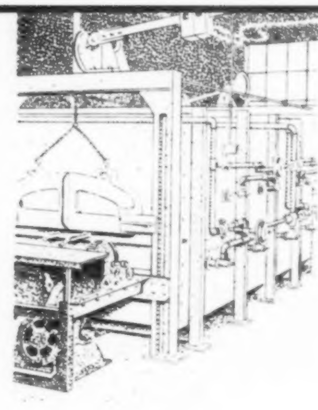
entirely to heat treating. They were then loaded into a hardening furnace and in some instances unloaded by hand and hand-quenched. In other instances the race rings were automatically conveyed from the hardening furnace into the quench tank. In any event, however, they were handled again at this point for washing off the quenching oil, and then hand-loaded into the tempering furnaces. Hand-quenched rings (and indeed many of the automatically-quenched rings) were sand-blasted or shot-blasted to remove hardening scale before being trucked to the grinding machines.

In the new manufacturing unit the race rings are conveyed in wire baskets at hand level from the screw machines to the heat treating furnace by overhead conveyer. It is an easy matter to switch off a basket of machined rings to the furnace loading platform. After the rings are loaded on the furnace belt, no further handling is involved until they emerge hardened, washed and tempered and ready for finish grinding.

The furnace layout consists of three complete units each with capacity of approximately 600 lb. per hr. Each unit is composed of an atmosphere generator, a hardening furnace, a quenching tank, a washing machine, and a tempering furnace.

The ball bearing race rings heat treated in these units are used in the construction of S.A.E. sizes (Series 200 from 210 to 216 and Series 300 from 302 to 315). The rings range in outside diameters from 0.5 to 6.5 in., with wall thicknesses from 0.125 to 0.625 in. They are made from electric furnace S.A.E. 52101 steel and are subjected to the following heat treatment:

Hardening temperature ..... 1500 to 1525° F.
Cycle in hardening furnace .. 20 to 60 min., depending on size and section.
Quenching medium .... Oil at 120 to 150° F.
Tempering temperature ..... 325° F.
Tempering cycle .... 90 min.



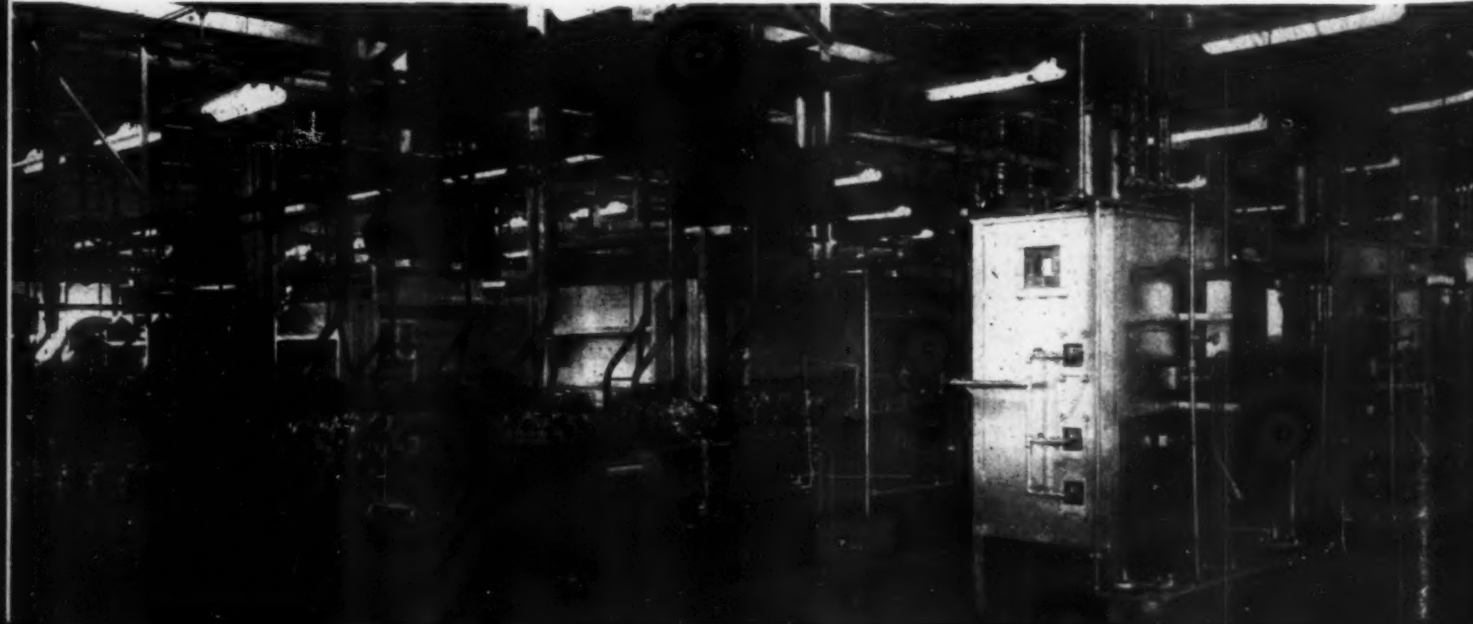
The hardening furnace carries the load through on an endless articulated belt which returns through the hot zone. Work is loaded by a vibrating feeder. The furnace is fired both above and below the working conveyer by radiant tubes under negative pressure; thus, in the event of tube rupture, the products of combustion cannot contaminate the furnace atmosphere and the bearing races being treated.

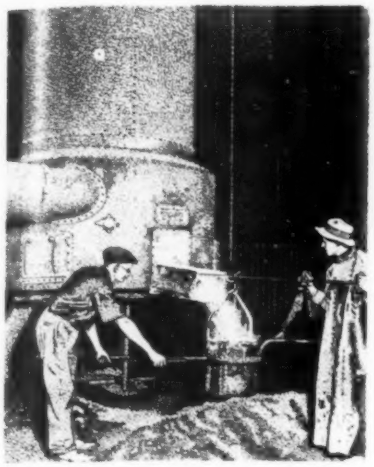
Race rings discharge automatically from the furnace into specially designed quench tanks fitted with elevating conveyer and properly designed agitation. They then proceed automatically to a spray washer and to a low-temperature tempering furnace with recirculating atmosphere (Fig. 5).

The hardening furnace atmosphere is generated by Surface Combustion Corp. "RX" machines. Rings must be C-61 to 63 hard — tested magnetically to this range by an automatic machine.

The various phases of the heat treating operation are under close metallurgical laboratory control. Composition of the furnace atmosphere is periodically determined, its dew point, the moisture content and temperature of the quenching oil, the surface condition of the race rings for carburization, decarburization or oxidation, the furnace temperature in various zones, the furnace cycles, the internal structure of the treated rings by fracture tests, and the composition and temperature of the washing compound.

Fig. 4 — Atmosphere Generators and Control Panels at Right. At left is charging end of three furnace lines for hardening and tempering of ball bearing races. Capacity of installation: 1800 lb. per hr.





Gray Iron Castings

INTERNATIONAL Harvester's facilities for producing gray iron castings have been vastly improved in quality and in quantity. Capacity for automotive-type castings only (tractor and truck) is currently 1650 tons melt per day. A tractor foundry is under construction for an additional 600 tons melt per day.

Assembly of molds is now largely done on continuous molding units, with castings segregated on "heavy", "intermediate" and "light" squeezer units. The sand used on these units is continuously processed, tested and controlled to a degree thought impossible 20 years ago. Laboratory control of moisture (held at lowest practical limits), strength, seacoal content, plus proper processing, make this possible.

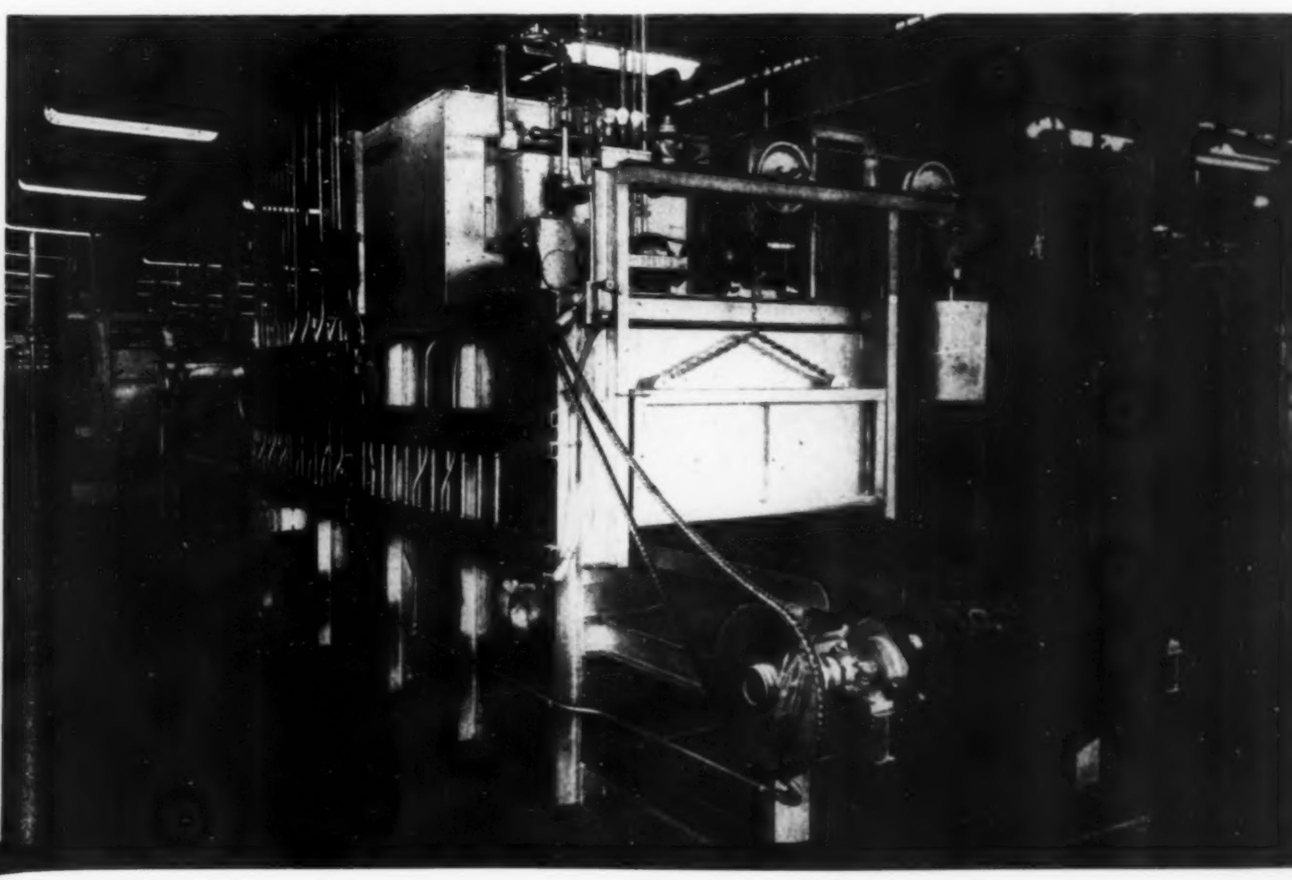
Core production is subject to the same type of control. Raw materials, mixtures, baking cycles in continuous ovens with automatic temperature regulation, are all subject to laboratory control and supervision.

Molds are poured with ladles traveling at the same speed as the mold conveyers. Castings then cool in hooded, exhausted "tunnels", shaken out mechanically and transferred to "beef lines", bucket conveyers, or apron conveyers for further cooling while traveling to the cleaning department.

In the cleaning department airless shotblasting cabinets and rooms have largely replaced tumbling barrels and have completely replaced sandblasting. Larger castings travel through the shotblasting rooms on conveyers, while smaller ones are cleaned in batches in the cabinet-type where they are tumbled and shotblasted simultaneously. After chipping, grinding and inspection (and, on certain types, pressure testing and hardness testing), castings go to the machine shops or storage by conveyer or truck.

Elaborate provision for exhaust is made at all points where dust originates. Special cooling is used for men at shakeout stations and other points where operating temperatures are high.

Fig. 5 — Discharge End of One of the Three Furnace Lines for Hardening the Ball Bearing Races. Tempering of quenched and washed rings is done in recirculating, controlled atmosphere. Finished work has not changed in surface carbon



The production of molten metal is under direct supervision of the foundry metallurgical staffs. All incoming raw materials are subject to analysis, visual inspection, proper storing, and segregation. The cupola mixtures of pig irons, steel scrap, gray iron scrap (both purchased and remelt) are computed by the foundry metallurgists. Charges are made up by crane and magnet, weights are recorded by the scale mechanisms. The coke used on beds and between charges is weighed and recorded. Metal portions of charges are charged by crane in cone-bottomed buckets; coke and flux (limestone or dolomite) in hinged-bottom buckets. Air blast is supplied by blowers having automatic air-weight controls; blast weight per minute and pressure are recorded continuously. Griffin hot blast systems are employed on cupolas for better operation and fuel economy.

Molten metal flows continuously from cupolas into 6-ton mixing ladles. Chill tests are taken at 15-min. intervals to check on depth of chill (and roughly on carbon content) by observing the character of the fracture. Transverse test bars are poured at intervals and sent to the plant laboratories for routine chemical analyses, strength and hardness tests. Microstructures of certain castings, especially for wear resisting and heat resisting applications, are observed at intervals. Metal temperatures at cupola spouts are taken and recorded at 15-min. intervals. Pouring temperatures of certain castings are likewise observed at pouring stations.

The base iron from cupolas is modified by late alloy additions to produce higher silicon irons for light castings, higher chromium iron for certain heat applications, copper-chromium, nickel-chromium and molybdenum for parts requiring higher strength and wear resistance.

All tractor motors in current production are valve-in-head and employ replaceable dry cylinder liners or wet cylinder sleeves. Thus, all heads, sleeves and liners are given special attention for conformance to specifications for hardness and microstructure. Transmission cases, main frames, rear axle carriers and rear wheels are a few of the many gray iron castings going into tractors that get rigid inspection. On the largest size International Harvester "Farmall" tractors, diesel engines are optional. Alloy gray iron cylinder heads are heat treated at 1050° F. for stress relief, as are all diesel crankcases. The dry-type cylinder liners are oil quenched and drawn to Brinell 500.

Valve guides and dry cylinder liners are stress relieved at 1025° F. before machining. All pistons are mild annealed (1225° F.). Heat control valves, made with fairly high chromium content, are annealed at 1400° F. before machining. Alloy gray iron exhaust manifolds for certain kerosene-burning motors are also stress relieved.

All gray iron castings are made in conformance with our own specifications ("I.H. E-6") used by all divisions of the company. These specifications are kept up to date as new irons are put in production.

All of the above gives but a brief picture of gray iron casting production and control today. It is a far cry from generally prevailing conditions of 20 years ago. At that time, molding sand was heaped on the floor; the sand could not be properly controlled by adding materials to the heaps and cutting in with a sand cutter. If the moisture content of the sand heap was too high or too low no really effective correction could be made in time. Metal usually was tapped intermittently and was carried and poured with hand ladles. Cupola raw materials were not weighed as accurately and in many cases only measured. Foundry buildings were not as well exhausted nor cooled at the high-temperature working areas. Foundry metallurgical staffs did not exist in certain foundries and where they were employed they did not have the well-equipped foundry laboratories so common today.

Fig. 6 — Two Ovens of Old Type for Annealing Malleable Iron. Castings were packed in containers or pots with inert granular material for support, and the pots stacked three or four high. Heat treatment cycle was seven to ten days

Short Cycle Malleable

Malleable castings, "black-heart malleable", were first produced about 125 years ago. For about 100 years, white iron castings were annealed in pots, packed in a mildly active material. The ovens, large brick structures (Fig. 6), were loaded with pots, the door mudded up, and firing proceeded for three or four days, whereupon the charge was allowed to cool, the total cycle ranging from seven to ten days.

In the early '20's, several long tunnel kilns, which had been used in other industries, were installed for malleableizing castings. Most of these kilns are in current use. Pots similar to those used in the batch-type ovens are loaded on cars which are pushed through the kilns in schedules of 10 to 20 cars per day. With 60 cars in the kiln, the "cycle" becomes a matter of three to six days.

This equipment was a definite advance through greater thermal efficiency, since only the castings and the pots were heated and cooled. The product was of a uniform degree, and less over-all time was required to get the product through the anneal and into the shipping room. This equipment also made possible a steady flow of product and a cleaner, more orderly operation — conditions which were not easily obtained with the large batch-type ovens.

These kilns are necessarily long, however, and require at least 40 tons per day to operate efficiently — without dummy cars, that is. They make no provision for a mixture of large and small castings and do not take advantage of possible changes in silicon content in the iron, except in an over-all manner; the cycle is set for the heaviest section and the lowest silicon. Pots weigh roughly twice as much as the castings they contain, with the result that in practice three pounds of metal are heated to anneal one pound of casting.

For many years International Harvester's malleable foundry has operated two air furnaces which melted two heats a day, and which produced 140 tons of castings per week. These castings are small, light in section and quite fittingly referred to as "jewelry". With a little more than

Fig. 7 — Discharge End of New Type of Continuous Furnace Equipment Wherein Light-Walled Containers Filled With White Iron Castings Are Annealed in 14½ Hr.

normal silicon, such castings may be annealed in a few hours.

About ten years ago, Harvester metallurgists established the fact that a casting up to 1 in. in cross section would remain clear with a silicon content of 1.60 to 1.80%, providing the carbon content was in line, the metal properly skimmed, and the casting given a chance to cool rapidly.

It was learned that the carbon should be between 2.10 and 2.30% and that the total of carbon and silicon should not be greater than 3.90. It was also concluded that it was safer to control the mottling of the hard iron on the basis of the carbon and silicon total rather than on the basis of "carbon equivalent" (using $\frac{1}{3}$ as the silicon factor). A carbon equivalent of 2.83 based on 1.60% silicon and 2.30% carbon should be clear. A carbon equivalent of 2.80 based on a 1.80% silicon and a 2.20% carbon was not good.

It was learned that iron melted under favorable conditions with respect to oxidation and containing 1.55% silicon would retain no massive cementite after 3 hr. at 1725° F.; also that it requires the same time to complete the first stage of the anneal if the silicon is 1.80%. There apparently is a minimum time required to complete the first stage, and an increase in silicon above a certain figure is not effective in reducing the time required. There may be contradictory data, for it would seem that 0.20 more silicon would further reduce the time required. However, taking into account the difference in sizes and the casting cooling rate, and allowing 30 min. for contingencies, an annealing cycle was established based on a 3.5-hr. holding period at 1725° F. The slow cooling period was established as 6 hr. from 1500 to 1200° F. — about 50° per hr.

Furnace equipment was then based on a holding time of 3½ hr. at 1725° F., a cooling time of 6 hr., and a production requirement of 20 tons per day. With the heat-up, fast cool, and final cool, the cycle worked out to 14½ hr. The furnace is operated on a 28-min. push, 800 lb. of castings entering the furnace.

The containers weigh about half as much as the castings with the result that only 3 lb. of metal is heated to anneal 2 lb. of castings. (In the tunnel kiln it is necessary to heat 6 lb. of metal to anneal 2 lb. of castings.) The gas consumption is 1300 B.t.u. per lb. of castings.

As shown in Fig. 7 the furnace is gas-fired through 5-in. cast alloy radiant tubes. An externally prepared gas, containing 2 parts of CO to 1 part of CO_2, enters the furnace in the fast cool zone and works slowly toward both charge and discharge ends, filling the furnace. The castings emerge free from scale and are used without cleaning after annealing. The furnace has operated for over 10 years, as long as 18 months without being shut down, and has never been forced down because of failure of burner or mechanical equipment.

For several years a record was kept of the different patterns which had been made in the short-cycle iron. During the first four years of operation, approximately 4000 different patterns were run, all without changing any gating from the practice suitable for long-cycle anneals.

The physical properties of the iron are somewhat higher than A.S.T.M. grade No. 32510 (50,000 psi. min. tensile strength, 32,500 psi. min. yield, and 10% min. elongation in 2 in.). When the furnace was first operated, the slow cool was somewhat more deliberate than the present 50° per hr., under which condition the iron showed elongation percentages quite consistently of 18% in 2 in. and over.

As the castings produced are of No. 32510, metallurgists were not interested in obtaining 18% elongation. Accordingly, the castings were allowed to cool more or less with the furnace — that is, no effort was made to decrease the rate of cool in the slow cool period. The iron as now produced, and for the past seven years, will show a 55,000-psi. tensile strength, 40,000-psi. yield point, and 12% elongation.

The castings produced are not all in the "jewelry" class. Harvester regularly anneals binder needles and guards, mower guards, tractor foot pedals and brackets, as well as chain links, roller bearing end rings, wing nuts and levers, the latter being definitely in the small casting class.

The overnight anneal has enabled the foundry to put a pattern in the sand in the morning and to ship the castings the following day. This service to production lines is invaluable, even if it applies only in cases of emergency.

Editor's Conclusion

In this paper it has been shown that a large and representative firm, centering in the Chicago region, has been able to improve its product markedly by the application of the unfolding science of metallurgy. Its products are used far and wide in an essential activity of mankind. We believe it is not too congratulatory to International Harvester Co. to say that the record proves that no small part of the present high standard of living in America and the ability to produce a surplus for less fortunate friends in other countries is due to the activity of metallurgists. Nor is this situation unique. It is but typical of progressive machinery and tool manufacturers this whole country over.

Diesel-Electric Railroad Motive Power

By L. E. Simon
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An interesting example of the principle that men are paramount to machines comes from the history of the gas-electric locomotive. The essential units were designed and assembled into efficient railcars long before there were a sufficient number of railroad mechanics available for maintenance. World War I, with its start toward mechanized ordnance, produced a new crop of maintenance men; the two-cycle diesel furnished the efficient power unit; modern welding of steel plates and shapes offered a rugged constructional method; low-cost byproduct fuel oil promised notable economies; astounding performance records of carefully engineered and well-built locomotives appealed to cost-conscious railroad operators and maintenance superintendents. Thereupon, the diesel-electric locomotive, in coupled standardized units, was a "natural".

THE RISING STAR of the diesel-electric locomotive on American railroads has become very apparent to the public eye in recent years. Statistically the facts may be plotted as percentage of diesel-electrics to total locomotives ordered, year by year. Sales starting from less than 10% of the locomotives ordered in 1929-1931 jumped to over 50% in 1932 and have stayed there ever since except in the bad years of 1934 and 1936, growing steadily until over 90% of the locomotives ordered in 1946 attest to the utility of this type of motive power.

The plant of one of the major producers of the diesel-electric locomotive, and the pioneer in its entry into the passenger and freight main-line service, is located in the Chicago area. In 12 years this plant grew from humble beginnings to where it occupies an area of over 2,500,000 sq.ft., and is capable of producing 1,800,000 locomotive horsepower per year.

Yet the fundamental idea is by no means so young. From the early days of commercial usage of the internal combustion engine the idea that this type of power could be applied to railroad service occurred to several organizations. The higher thermal efficiency (compared to a reciprocating steam engine) promised more efficient railroading; however, several factors other than thermal efficiency entered the picture. Principal among these was the almost complete absence of shop men capable of maintaining the new type of equipment. Following World War I some of these problems resolved themselves, since mechanics became familiar with gasoline engines during the war. Others were recruited from the growing automobile industry. At this time the necessity for reducing operating costs on branch-line operations of the American railroads was also apparent.

In 1922 an engineering concern known as the Electro-Motive Co. was incorporated at Cleveland which was the predecessor of the later development in the Chicago area. This group introduced satisfactory designs of a number of components such as a gasoline engine especially built for railroad service, an electric transmission, railroad-type trucks, and also built up a strong service organization which resulted in successful railcars for railroad application. Many of these early units

are still in branch-line service on principal American railroads — frequently in the form of a combination power-mail-baggage-express car that can haul two or three ordinary passenger coaches.

Development of the commercial two-cycle diesel engine by General Motors, and acquisition of the Winton Engine Co. (which supplied Electro-Motive with gasoline engines) and also of Electro-Motive itself in 1932, initiated the phase of more intensive development which resulted in the Chicago manufacturing plant being erected in 1935.

By 1938 the Electro-Motive division of General Motors was producing at La Grange all major components of the diesel-electric locomotive, including an all-welded car body structure, the complete engine, and the heavy-duty electric generators and traction motors.

The Author

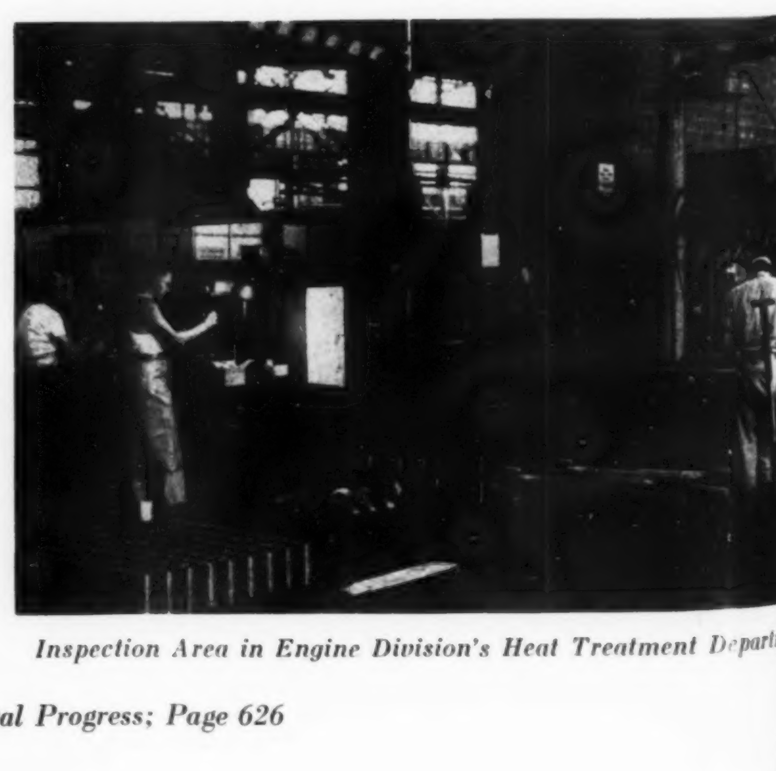
As is well known, the modern locomotive consists of one to four units, substantially identical as to mechanical features, coupled together to give traction necessary for intended service. The individual unit of the diesel-electric locomotive weighs in the neighborhood of 225,000 lb. and a complete four-unit locomotive of the heavy-duty freight or passenger type will weigh almost 1,000,000 lb. (500 tons) as delivered. Exclusive of nuts, bolts and washers, and counting the engine, generator and traction motors as one part, there are approximately 14,000 pieces in a unit of a locomotive. Since the major part of the weight is metal, metallurgy has played an important part in the product from its earliest days.

Electro-Motive's growth was based on the production of a standard type of diesel-electric locomotive which, with minor modifications, could be used in a wide range of railroad applications. This conception of design and manufacture allowed the widest exploitation of modern welding in its most reliable and economical forms.

The car body structure is completely fabricated by welding, and is so designed as to distribute the stresses throughout the structure rather than carry all the load in the underframe. This closed box structure is built with diagonal bracing in the sideframes so as to offer rigidity. The materials entering the car body are primarily wrought mill products such as I-beams, channels, angles, and plates, although some forgings and castings are used. All these materials are specified and purchased especially so as to be suitable for joining by arc welding.

The crankcase for the diesel engine (which is arranged so the individual cylinder assemblies and most of the auxiliaries can be bolted on) is made from wrought materials which are specified so as to lend themselves to joining by the welding processes. The engine design is such as to permit manufacture of 6, 8, 12, or 16-cylinder engines with the same basic cross section but varying in horsepower depending on how many cylinders are used. This design, of course, lends itself well to quantity production.

Early locomotives were produced as a cottage is built, by starting with an under-



Inspection Area in Engine Division's Heat Treatment Departm

frame and adding pieces until the structure was completed. As volume increased it became possible to take advantage of certain principles which improved quality and resulted in lower costs. The use of subassemblies, control of fitup and welding sequence, extensive use of downhand welding, and the application of automatic welding processes all contributed to these ends.

As is well known to metallurgical engineers, the joining of metals by fusion welding is accompanied by dimensional contraction across the joint, whose amount is approximately proportional to the amount of metal deposited in this joint. For this reason the gap to be filled with weld metal must be accurately controlled in order to arrive at proper finished dimensions of a weldment such as a car structure from 50 to 70 ft. long. The sequence of deposition of various passes of weld metal in a complex weldment also affects the over-all distortion, and it is therefore necessary that the sequence be established and maintained. These factors are especially important in a part such as a diesel engine crankcase — really the foundation of the engine — which is held to a size of 12 ft. 2¾ in. ± ⅛ in., as-welded and stress relieved, and to a dimension of 12 ft. 2.250 in. ± 0.005 in. when finish machined.

The use of subassemblies permits the widest possible use of jigs and fixtures for accurate control of fitup and sequence. The subassemblies also assist in controlling the over-all size of weldments, so that manipulators are applicable for positioning welds for the proper type of electrode to be used. American Welding Society's specification E-6020, 6030, 7020, and 7030 electrodes permit the highest welding speeds and also the highest quality of deposited weld metal. Since these electrodes are usable only in the downhand welding position, manipulators such as shown on the next page have been instrumental in their wide use, thereby attaining high quality and reasonable cost. Jigs for making, complete, a car roof upside down have been constructed. The volume of welding has grown to where 1,500,000 lb. of coated welding electrode was used at the La Grange plant during 1946.

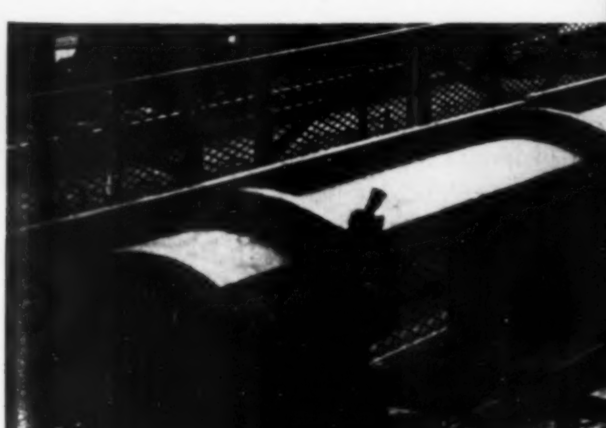
Where heavier metal sections are joined it often becomes economical to apply the weld metal by an automatic process. Through the years this trend has been followed in diesel-electric locomotive manufacture and today we have in operation nine automatic welding machines of the submerged-arc type and one of the coated-electrode type. Electrodes for such equipment amounted to 115,000 lb. during 1946.

Certain structures lend themselves to manufacture by spot welding and use has been made of this method of joining to the extent that eight spot welders are in operation joining metals ranging from 16 gage to ⅜ in. thickness. The photograph reproduced below illustrates one of the newer machines of this type mounted on a car which operates cross-wise of the crane bay in a fenced aisle, and capable of reaching any point on a narrow welding floor at either side.

Quality Control

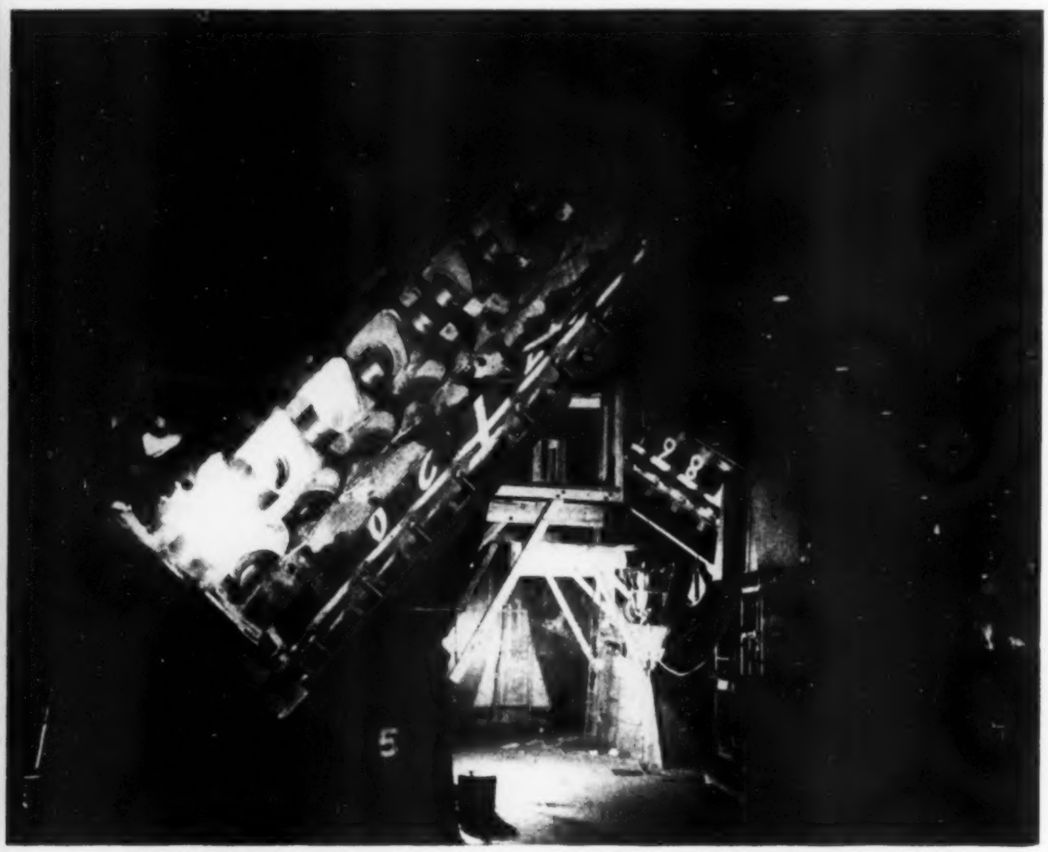
Metallurgical quality control is exercised by the inspection and test department, and the metallurgical section of the engineering department. Casting and forging inspection, metallurgical inspection at the receiving department, crankshaft and camshaft inspection, heat treat inspection, axle Magnaflux, welding inspection and source inspection combine to insure that sound material

Semiportable Spot Welder at Work on a Long Car Section

is applied and properly processed. The material control laboratory and the metallurgical laboratory assist in establishing inspection procedures and perform those tests requiring laboratory facilities such as chemical analysis, viscosity, fire and flash, tensile tests, impact, metallographic tests, profilograph, Knoop hardness, arc heights, and deep etch. In addition, the laboratory carries on continuous work with the engineering design sections to apply new materials and to improve the design of the whole engine.

The routine metallurgical inspection points have grown in area with the plant and are equipped for various types of hardness tests, fracture tests, and Magnaflux inspection. Laboratory facilities have also grown with the years and now comprise the material control laboratory and the metallurgical laboratory which encompass a total area of 11,000 sq.ft.



Turret-Like Manipulators Turn a 16-Cylinder Engine's Crankcase About so That All Welding Can Be Done in Downhand Position

Metallurgical processes are automatically controlled wherever possible, there being 255 instruments for temperature control in use. These instruments are maintained and calibrated by a pyrometer maintenance group.

Heat treatment, which is practiced extensively in order to improve metal properties, is conducted in a modern heat treatment department. All carburizing is done in electrically heated, pit-type, gas carburizing furnaces. Hardening is done in electrically heated, pit-type or box-type atmosphere furnaces. Salt bath heat treatment is carried out in electrode heated equipment. Tempering is conducted in high-velocity convected-air furnaces. The heat treatment department of the engine division is also equipped for grit cleaning and for shot cleaning, as well as peening operations to improve fatigue resistance of such important members as main drive gears.

Plating of silver, copper, and cadmium, as well as lubrizing, are handled in a specialized plating department which is currently undergoing an expansion of facilities.

To insure the utmost in temperature and cycle control the stress relieving of weldments and process stress relieving on steel and cast iron parts are done in forced-convection, gas-heated furnaces which are located directly in the production line.

Conclusion

Within the short span of 12 years, in the Chicago area, has arisen from the prairies a plant equipped with the newest tools of the manufacturing art, devoted to supplying the American railroads with locomotives utilizing the most efficient and adaptable means of power. That the railroads agree with the statement in the last sentence is proven by the fact that more than 90 out of every 100 new locomotives ordered are now of the diesel-electric type. Twenty years ago the average mileage accumulated by a steam locomotive was 34,000 miles per year. Today the diesel-electrics average 220,000 in passenger service and 100,000 miles per year in freight service. Several of the first diesel-electric locomotives built in the La Grange plant have accumulated over 3,500,000 miles and are still going strong.

Metallurgical Progress in the Valve, Fitting and Piping Industry

By J. J. Kanter
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Crane Co., Chicago

Viewing the valve industry as an outgrowth from the brass founding industry, the author (who has taken a prominent part in the development of metals for high-temperature, high-pressure service) writes an introduction to two of the subsequent articles describing important advances in Crane Co.'s foundries during the past 30 years. A great deal of work has been required to coordinate other phases of manufacture of even the commonest types of valves and fittings. Fundamental to the production of controls for more severe services, of course, is a sound knowledge of metallurgical properties.

DEVELOPMENTS in the manufacture of valves, fittings and piping materials are intimately identified with the changing techniques, arts, and sciences of metalcraft. Metals and their alloys have furnished the principal materials wherewith have been achieved the many intricate controls of the flow of fluids on which our modern industries and culture are utterly dependent. As new metals and metalworking methods became available this industry has been prompt in adapting them to its products. Numerous problems, unique to equipment for controlling fluids, have prompted this industry to pioneer much development, research and engineering of a metallurgical nature. It will be the aim of this paper to recount these developments, briefly.

In our present way of living we take these things quite for granted. Hot and cold running water, sanitary plumbing, fuel for cooking and heating — all these items, familiar to us in our daily lives, represent control over fluids. Within a generation or two they have helped construct the American mode of living. Beyond these controls familiar in the household are further controls over fluids better known to the engineer, but nevertheless fundamental to the functioning of our household conveniences. These are the devices needed to control flow in the waterworks, the central power station, the oil refinery, the chemical plant, the factory and mill. Probably such behind-the-scenes controls overshadow, in industrial importance and volume, those familiar to the householder. The development and manufacture of each item, whether for domestic purposes or for heavy industry, contains a story having to do with the endless possibilities of the metals and alloys used in their embodiment.

Of basic importance to the manufacturers of valves and fittings are the techniques of the foundry. Possibly the industry had its origin in the foundryman's craft. Even today, the most of the metal finding its way into valves and fittings is handled through foundries specialized for brass and bronze, gray iron, malleable iron, and steel. During the past three decades, the period under review in this issue of *Metal Progress*, important developments have taken place in the manufacture of this equipment from forged and automatic screw machine parts, but the foundry still stands as the basic unit of manufacturing operation. To match the pace of the other metal manufacturing departments, the foundry has become mechanized to an amazing degree, and therefore is able to hold up its end in efficiency, uniformity and dependability of products, and has become an agreeable

and interesting place of employment. It therefore seems fitting in a review of industrial progress in the valve and fitting industry to present some views of modernized foundries devoted to such manufacture, and this has been done in the subsequent articles on steel founding and on brass foundry practice.

The modern manufacture of products — integrating the operations of foundries, forge shops, welding shops, machine shops, assembly belts and inspections over all operations — is necessarily preceded by a considerable program of research, development and engineering. Constantly new applications are being found for valves, fittings and piping where fluids — sometimes of entirely new nature — are to be conveyed under new extremes of temperature and pressure. Each of these developments occasions exhaustive inquiry into the materials and mechanical problems implied. Such investigation entails the maintenance of numerous specialized facilities for metallurgical and mechanical research.

Numerous examples of developments in the field of valves and fittings intimately allied with the progress of metallurgical techniques might be cited. None is more suggestive of progress than the present-day steel valves for high-pressure, high-temperature services.

Until the advent of superheated steam, cast iron or bronze valves were quite satisfactory. Experience with saturated steam at pressures up to several hundred psi. and temperatures not exceeding about 500° F. indicated that cast iron and brass valves were quite suitable. However, attempts to impress them into higher ranges of temperature and pressure were not feasible. With advance of temperature beyond 500° F., the need for steel valves and fittings was firmly established; they have undergone four decades of fascinating development.

The earliest steel valves were hardly more than cast iron designs into which bessemer blown steel was substituted. From this beginning has evolved a highly developed technique of founding steel castings, comprised of numerous alloy steels suitable for special services. Designs of steel valves more suited to forging or weld fabrication techniques than castings have also been forthcoming. The result is that the valves and fittings available today in steel and its alloys represent a comprehensive integration of manufacturing facilities.

Today the requirements for alloy steel steam valves rated for 1500-lb. pressure at temperatures up to 1000° F. have become well established. Such a valve, in 8-in. size for example, weighs 985 lb. and is shown in the photographic portion of Fig. 2. This valve incorporates the advantages of design obtainable through the advances in steel metallurgy, welding and founding techniques. The trend in high-pressure piping systems is to replace bolted connections with compact welding ends, and a bonnet designed to seal through the influence of internal pressure rather than the stressing of bolts. Elimination of the bonnet flange in this manner has reduced the weight from 1910 lb. (for the 8-in. size depicted by the black shadow in Fig. 1) to the present 985 lb.

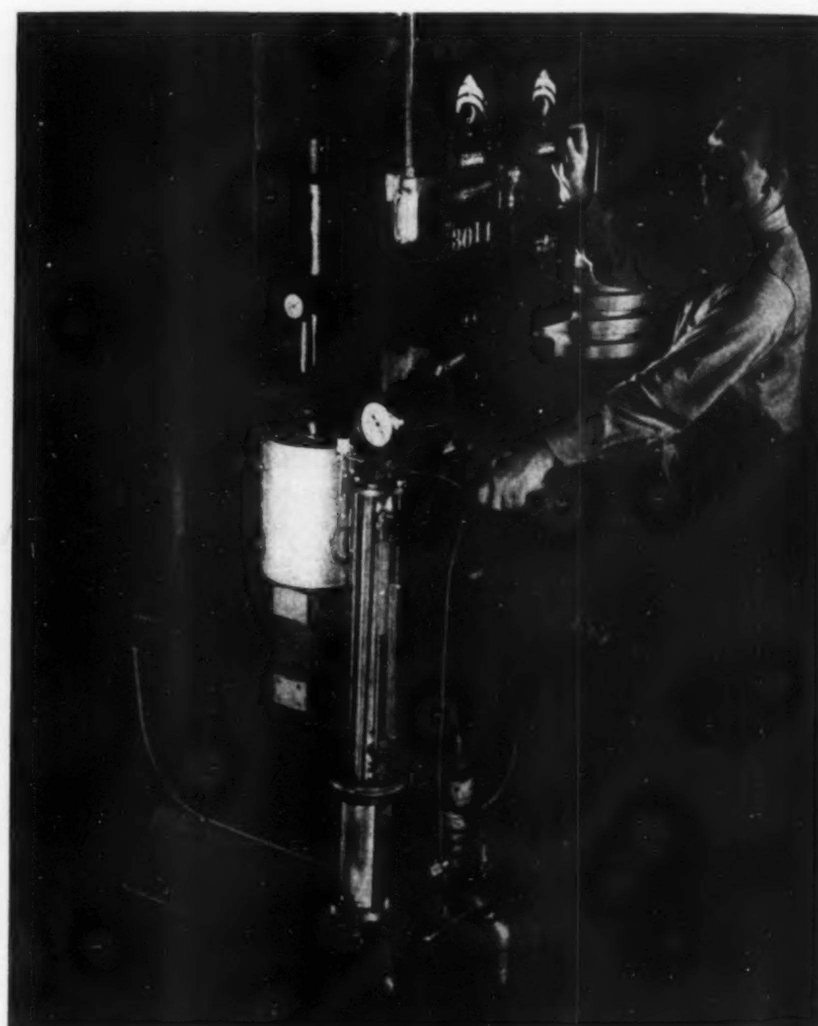

Fig. 1 — Wear and Seizure Studies of Metals Are Pertinent to Best Operation of Valves

Savings Through Welding

More impressive yet is the over-all saving by substituting the welding process for bolting and end flanges. Adding companion flanges, bolts and nuts to an 8-in. steel valve made a total weight of 3228 lb. Contrasting this with the present 985 lb. we find that improved design, materials and methods have made possible a high-pressure steel valve weighing only about 30% as much as the standard of only a few years prior to the recent war.

Examples of developments in this industry might be further enumerated to illustrate the important role that metallurgical art plays. There might be cited the influence which electroplating techniques have had upon the design and styling of plumbing fixtures. Many industrial applications involve hard facing materials and depositing techniques are used with valves for automatic operation. Modern hard brazing technique has introduced new possibilities in manufacturing equipment for high vacuum systems. The application of die castings, precision castings, centrifugal castings, permanent mold castings, and sintered powdered products might be cited, as adapted to the complex problem of properly controlling fluid flow. However, since the thought here expressed is that this industry had its essential development out of the foundry arts, the following two companion articles have been prepared to convey the modern technical aspects of such operations.

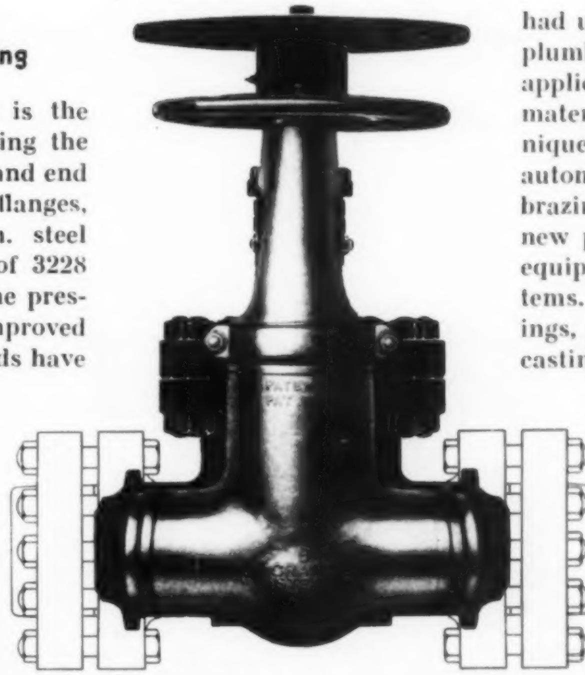

Fig. 2 — Modern 8-In. Steel Valve With Pressure Sealing and Welding End, Shadowed by Its Much Heavier Predecessor With Bolted End and Bonnet Flanges. Weight of old standard (bolted flanges): 3228 lb.; present-day valve: 985 lb.

Thirty Years in Steel Founding

By H. W. Maack
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THE 30-year period which began in 1917, when the Chicago "Steel Treaters" first organized, embraces extremes of flush and lean times, as measured in volume of steel castings produced; it also contains many outstanding developments in metallurgy. War demands were directly accountable for record production of castings during two four-year periods; depression stagnancy for a record low. Development of improved practices, although probably speeded by war, can reasonably be considered to have been progressive over the whole 30-year period, for adversities, whether in peace or war, call for man's best efforts.

The intent of this article is to review briefly the 30-year history of this industry and the import of the advances made, particularly in relation to a steel foundry producing castings for valves and fittings — a very important field of use. Similar improvements have been made in many other foundries, and the present case is cited as typical of such progress.

Melting Equipment

In 1917 Crane Co. made steel for castings by the side-blown converter; its use had been started in 1907 (believed to be the first installation in the Chicago area for making steel for castings). The year 1918 marked the peak production of converter process steel for castings in the U. S., and in 1919 the ascending electric furnace process surpassed it. Early in the latter year a Heroult electric steel melting furnace was installed in the Crane Co.'s foundry to supplement and soon succeed the converters.

Quality of the steel produced, from the viewpoint of its foundry characteristics or castability as well as strength and other mechanical properties and economy or cost per ton, was the principal reason for the change from bessemer to electric steel. The converter process at its peak accounted for 11.4% of the total American production of steel castings.

Thirty years ago the use of electric furnaces for melting steel for castings was a comparatively new venture. From the reports of the American Iron & Steel Institute, the first such use was in 1908, and in 1917 only 4.5% of the total tonnage of steel produced for castings was melted in electric furnaces. In 1946, the proportion had grown to 48.3%.

Electric arc furnaces for steel melting have been markedly improved during 30 years. Structurally, the tilting mechanisms are superior, water cooling of critical parts has been extended to include the power cables, furnace roofs are moved aside hydraulically for charging by bucket. New and better automatic electrode controls have been developed, and electrode holders improved to simplify the slipping and changing of electrodes. Electrically, safer power transformers with greatly increased capacity are used, thus reducing the melting time per heat. All these advances have made for faster melting and increased production. Steel of highest quality is made, basic melting practice permitting a thorough refining of the bath.

The year 1947 marks the 30th anniversary of the invention of high frequency electric induction melting of metal by Prof. Edwin F. Northrup, working in the Palmer Laboratory of Princeton University. Today melting furnaces based on high frequency induction heating are used in many countries, total power for these installations exceeds 300,000 kw., and capacity of individual furnace ranges from ounces up to eight tons.

Induction furnaces are used in many foundries to melt steel and other alloys for pouring small castings. They permit the foundryman to maintain a uniform temperature from beginning to end of pour, thus minimizing losses from misruns. Also they permit the melting of low-carbon steel without carbon pickup, a big advantage in such types as 18-8 chromium-nickel stainless steels in which low carbon is essential for best corrosion resistance after welding. Induction melting is simple and fast, and results are easily reproducible, heat after heat.

The so-called triplex process has been developed in recent years. A charge of iron or steel scrap or a mixture of both is melted in a cupola, the molten iron blown in a converter to make steel, and then brought to the required composition and temperature in an electric arc furnace. (Sometimes a dephosphorizing treatment is also used.) Such multiple-step processes are expensive in final cost of steel, as might be expected, but they have advantages where a constant supply of metal is needed for continuous pouring.

Fig. 3 — A Battery of High Frequency Induction Furnaces in Crane Co.'s Steel Foundry

Alloy Steel Castings

Of the 1917 total production, castings of alloy steels accounted for only 75,632 tons, or 4.7%. Thirty years later shipments of alloy castings had increased to 319,806 tons or 22.3% of the total. This trend is indicative of industrial progress for it reflects the need for stronger or tougher steels, or those with improved corrosion resistance or heat resistance.

In the valve and fitting industry, carbon steel castings appear to have been adequate until about

1923. Then the petroleum industry voiced a need for valves with improved strength and corrosion resistance and a low-alloy nickel-chromium-molybdenum steel was produced having about 50% greater strength than carbon steel. This was followed about five years later by 5% chromium steel containing 0.5% molybdenum; it had superior corrosion resistance to hot, sulphur-bearing petroleum vapors. Similarly, more highly alloyed steels for castings were developed as need arose. In 1928 valves were made of 18-8 chromium-nickel steel, principally for their superior corrosion resistance to sea water. Castings of many other alloy steels are made as the need for high strength or resistance to corrosion, heat, or shock dictates.

Heat Treatment

Suitable heat treatment is essential to bring out fully the latent mechanical properties of steel castings. This may be a simple anneal or normalize, normalize followed by tempering, or a liquid quench followed by tempering. The choice depends upon the steel composition, the size and shape of the casting, and the mechanical properties required. Years ago annealing only was the commonly used heat treatment. Although often good enough for carbon steel castings, with the advent of alloy steel a simple anneal was no longer adequate.

Heat treating furnaces and temperature control equipment have been developed and vastly improved during the last 30 years. Modern furnaces apply heat efficiently and uniformly, thereby expediting the operation. Tempering or drawing furnaces are equipped with fans to circulate the hot gases around the castings, thus insuring uniform temperature. Controlled atmosphere can be used in furnace chambers to prevent scaling. Pyrometers are equipped for automatic temperature control through the operation of fuel valves; temperatures are indicated so the heat treater can know how hot the charge is at all times, and are recorded for later reference.

During World War II great progress was made through the use of continuous heat treating furnaces and timed quenching in oil or water, the quenchant being controlled at correct temperature and circulated properly around the hot castings. The progressive handling of these castings is often largely mechanical and automatic, resulting in

Fig. 4 — Line of Modern Furnaces For Heat Treating Steel Castings. Car bottoms come forward to deck of transfer car at front, to be transported to quenching tanks and loading station

exceptional mechanical properties not otherwise obtainable. Some authorities foresee permanent benefit to the steel casting industry as a result of this wartime experience.

To develop the maximum corrosion resistance in austenitic stainless steel castings, for example those of 18-8 chromium-nickel alloy, requires rapid cooling from the homogenizing temperature of about 2000° F. Therefore, castings of this material are regularly heat treated in this manner, quenching in water when the shapes allow.

Mechanical Handling Equipment

Thirty years ago the sole handling equipment in many steel foundries was an overhead crane. Among other duties it charged the furnace, lifted the molds, carried the molding sand and handled the ladle of molten steel for pouring. Demand for increased production and desire for labor-saving devices gradually extended the use of mechanical equipment until in today's modern foundry all possible handling is mechanized. Such changes in a modern valve and fitting foundry exemplify this trend.

Molding sand, from mixers to molding stations and from casting shakeout back to mixer, is conveyed on belts. Molds and flasks are moved on roller conveyers. Pouring ladles are carried by electric cranes. Castings are handled by overhead trolleys through various steps from shakeout to heat treatment cars. Charges are dropped from drop bottom buckets into electric melting furnaces, with roof swung aside. Samples of steel for analysis are sent to the laboratory by pneumatic tube, and analyses reported by Telautograph. Analyses are made by photo-electric, spectrographic, and other rapid methods. Castings are cleaned with high pressure water and in modern blasting machines.

Mechanization has increased production and at the same time reduced laborious handling, improved the safety of workmen, and made for continuous progressive production.

Fig. 5 — Circle of Castings (Gates and Risers Still Attached) and Film Holders Surrounding a Radium Capsule. Open safe for the radium at left

Radiographic Examination

Thirty years ago radiographic examination of metals was in its infancy. Roentgen or X-rays had been discovered in Germany in 1895 and used for metal examination in Europe, and by General Electric Co. in this country, during World War I. In September 1915, W. P. Davey of General Electric published a paper entitled "Metal Radiography", and early in 1923 H. H. Lester of Watertown Arsenal described X-ray examinations of steel castings there. The use of the gamma rays of radium for soundness of metal examinations was revealed by Mehl, Doan and Barrett of the U. S. Naval Research Laboratory in 1930. These nondestructive tests for soundness have since been of invaluable use in developing foundry techniques for steel castings.

During 30 years the technique and application of radiographic examination has advanced rapidly. Several 1,000,000-volt X-ray units are in use in the United States, and in 1944 the first industrial unit of 2,000,000-volt capacity was installed for the examination of large steel castings and forgings.

The practical value of radiography in steel founding, residing in the ability to reveal the degree of soundness without destructive dissecting of the casting, lies in its help in studying gating and feeding practices. If a number of castings of the same design are required, radiography of a pilot casting is the usual procedure. For single castings, or those for critical service applications, radiography of each may be required; examination may be 100% or only partial — that is, only those regions known to be prone to unsoundness may be examined. Such examination may reveal defects that can be repaired by welding. In any event, radiography has become an invaluable tool of the steel foundry.

Many foundries use both X-ray and gamma-ray radiography, the choice depending upon which is more convenient for the castings at hand. The number of castings to be inspected, their size, and the thickness and location of section to be examined are the determining factors.

Thus, the progressive steel founder of today has greater knowledge of casting design and riser or feeder size and arrangement to insure sound castings. He applies the principles of "controlled directional solidification", based on progressively feeding the sections in the order of increasing thickness. Shrink cavities are then confined to the feeders, last to solidify.

Magnetic Particle Inspection

Magnetizing steel castings and then applying iron powder to reveal the location and extent of shallow discontinuities by the magnetic poles induced thereby, to which the powder is attracted, is a comparatively new method for examination of steel parts. It is particularly useful in locating otherwise invisible surface cracks, the iron powder adhering to the edges of these discontinuities.

Magnetic particle inspection is a valuable method of testing steel castings for critical service where unsoundness, not otherwise detectable, might cause premature failure. For alloys which are not ferromagnetic — austenitic stainless steels, for example — other methods not based on magnetism are available such as a penetrating oil and fluorescent powder.

Research Foundry

Thirty years ago research in foundry methods and materials was comparatively rare. Rule of thumb practices commonly governed. Craftsmanship and skill were the quality factors. Subsequently, the need for organized research and its value were recognized, and today many manufacturing concerns have their own research organizations. Services of several institutional research laboratories are also available to industry.

Crane Co.'s research laboratories contain a well equipped foundry with facilities for melting, molding and pouring, and heat treating. Melting is done in high frequency induction furnaces powered by a 110-kw. motor-generator set. Furnaces can melt 200 lb. of steel, brass or cast iron. Heat treating furnaces are of conventional and controlled atmosphere types. Molding sand equipment includes a mixer for experimental and regular batches, and testing devices for all American Foundrymen's Assoc. standard tests. Molds are moved on roller conveyers and ladles are conveniently carried on overhead monorails. With facilities available for mechanical and physical property tests, dilatometric study, metallographic examination, and gas analysis, many problems in cast metals are here conveniently studied.

Fig. 6 — Optical Dilatometer Which Reveals Thermal Characteristics of Metals on a Photographic Film. This instrument is a most useful tool for determining correct heat treatment schedules. It also gives valuable clues to the weldability of alloy steels

Limitations of space forbid more than mere mention of many other advances which have contributed to the progress of the steel casting industry. Some of these are improved refractories (including ramming materials for monolithic furnace bottoms), improved furnace electrodes, molding sand control, and riser coverings of blanket and exothermic types.

Today, specification requirements for many grades of steel castings have been standardized, whereas 30 years ago there was only one American Society for Testing Materials' specification for them. Now more than 20 A.S.T.M. specifications cover dozens of grades of steel castings — an exceedingly helpful situation, not only to producer but to consumer of quality castings.

Brass Foundry Practice at Crane Co.

By H. M. St. John
Superintendent of Brass Foundry
Crane Co., Chicago

THE CASTING of brass and bronze in sand molds is a very ancient craft, just how ancient probably no one knows. It is sure, however, that for many centuries prior to the 20th there was little or no change in the brass founder's art. The alloys were mixed and melted in crucibles by men who had their own secret methods for getting desired results. Molders were highly skilled in the manual application of their craft and, in addition, had to be familiar with the idiosyncrasies of patterns of various sizes and shapes and the properties of available molding sands. Finally, in order to be sure that no one spoiled the results of his labor, the molder judged by eye the quality and condition of the molten metal and poured the mold himself.

Ninety-odd years ago, when Richard T. Crane started the brass foundry that grew into the present Crane Co. of Chicago, the practices followed were the same as they always had been, as far back as anyone could remember. An interesting reconstruction of the wooden building in which his start was made (interior showing some of the equipment) is photographed in Fig. 7. Secrecy was still an important factor in the alloying of brass and bronze — although it was probably the boss, rather than the melter, who possessed most of the shop's secrets. The molder, however, still made his own rules and saw to it that they were observed.

Relatively speaking, in the time cycle, the modern production foundry is a development of the last few years. It differs widely in every respect from the foundry of 100 or even 50 years ago. Tradition yet rules in the casting of statuary and ornamental bronzes, where the molder is still a highly skilled artisan. For more ordinary castings, if only a few are to be made from one pattern, mass production methods are not suitable and a molder of some skill and experience is needed, but in volume production the molder is now little more than a machine-hand who can be trained in a few weeks, as compared with years of apprenticeship once customary. The details of alloying and melting, the selection and testing of materials, and the control of quality are the responsibilities of supervisors and trained technicians who do not produce with their own hands.

Advanced practice in the brass foundry of only 30 years ago, when the A.S.M. started in Chicago, featured mechanical aids for removing crucibles from furnaces and for handling the metal during pouring; the melters produced more with less effort. Molders no longer poured their own molds and, by devoting their efforts exclusively to molding, greatly increased the production per unit of floor space. An overhead sand system conditioned the used molding sand and returned it to the molders, ready for use, in chutes directly above their machines. Molds were placed on power-driven carriers which transported them to the pouring zone and then to the shakeout. Such were the most advanced ideas of production during World War I.

More recent trends stress the importance of improved working conditions, of less hard labor, and of lower labor costs in terms of man-hours, of improved quality and greater dimensional uniformity of castings. As a result, production brass foundries are being mechanized to an increasing extent and all brass foundries, large and small, are employing more and more technical control over materials, processes and product quality.

Much brass is now melted in electric furnaces. Figure 9 shows a battery of induction furnaces in Crane Co.'s foundry for melting manganese bronze and some of the red brasses and bronzes. In their operation as compared with the coal-fired crucible furnaces shown in Fig. 8 (themselves the last word in modernity when they were put into operation in 1915), two men do the work of six and the job is a much more agreeable one. The greater part of the red metals (high-copper alloys) is melted in electric arc furnaces, as illustrated in Fig. 10. Crane Co.'s installation includes sizes varying from 250 to 1000-lb. capacity. Some of

these are also used for melting monel and other alloys with high melting point.

In its larger sizes, the arc furnace melts as much as 1000 lb. of metal in 30 min. and is almost completely automatic in its operation. The melter does little but adjust controls and press push buttons. Even the job of charging metal into the furnace is largely mechanical. The drum-shaped furnace body is mounted on rollers actuated by an electric motor, and rocks or rolls backward and forward during the melting period in order to keep the metal well mixed and insure an even distribution of heat between furnace lining and molten charge. The speed and amplitude of rocking action is governed by a controller which the melter adjusts at the beginning of the heat.

These arc furnaces are also equipped with meters showing the rate at which electric energy is being absorbed and the quantity of energy which has been consumed since the beginning of the heat. By means of these instruments the experienced operator can closely judge the temperature of the metal and can pour it when ready without danger of overheating. In both electric furnace types, induction and arc, the melting operation is closely controlled and the attainment of uniform metal quality is relatively easy.

Fig. 7 — Interior of Reconstructed Foundry Which Started Business in 1855 and Became the Predecessor of Crane Co. Charcoal fired furnace for melting in small clay crucibles shown in left background. Flasks, bench and hand tools still exist practically unchanged in all small foundries

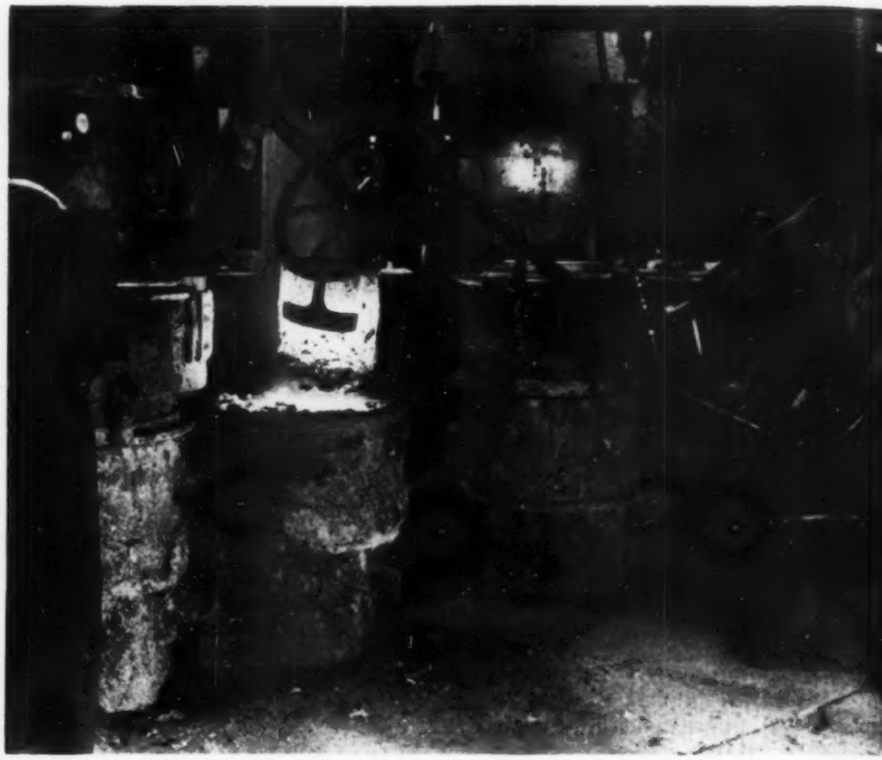
Purchased metal is chemically analyzed and carefully inspected to make sure that it is of the desired quality. The various charge constituents are calculated and weighed to insure that each alloy will be of correct composition after allowing for inevitable melting losses. Bars for tensile and other tests are cast to make sure the molten metal coming from the furnaces is of good quality; any deviation from standard is promptly detected and the necessary correctives applied.

Most nonferrous alloys are very sensitive to pouring temperature and care is taken to see that the metal going to the molds is, within close limits, in suitable condition. The best pouring temperature varies according to the alloy, the size and design of the casting, and the conditions to which the casting will be subjected in the hands of the customer. The high-zinc alloys may be poured as low as 1800° F., while pouring temperatures for the red metals (high in copper) will vary from 2050 to 2300° F. Temperature at which pouring begins is usually controlled to within ±20° F.; immersion-type thermocouples, thrust into a waiting ladle, transfer their readings to a giant scale pyrometer dial so all interested can see.

In our modernized foundry floor, molds are lifted from squeezers to small four-wheeled cars of appropriate size that run along either side of crosswise pouring aisles. These tracks are somewhat elevated to bring the top of the mold to convenient level for pouring. After the casting chills and the flasks and weights are removed, the little car is pushed off the far end of the track on a tilting mechanism which automatically slides the sand and casting on a pan conveyer leading to the cleaning room. The empty car then rolls back to the start of the line on a track at floor level. With this dumping equipment one of the foundry's most disagreeable tasks has become simple and easy. The ventilation provided for this particular floor keeps it almost completely free from smoke, dust, and heated air.

Defective castings are studied to determine the cause of trouble and the most effective remedy. In this way costs due to scrap losses are kept at a minimum and the ultimate consumer is assured of the highest attainable quality. This is a continuing program shared by all persons responsible for quality of castings.

Most of the materials used are purchased on specification. Of these possibly the most important are molding sands and



A massive central pillar mounts four furnace shells, and can swing them from the unloading station (shown in the view) around 180° to an opposite platform where the furnace is cleaned, a newly loaded crucible charged and packed tightly about with coal, the cover placed and the fuel ignited. A downdraft forces the smoke out through the central pillar. Combustion is continuous at any of the four stations until the charge in the crucible is melted and ready to be removed.

Fig. 8 — Advanced Type of Brass Melting Furnace; Crane Co.'s Design as of 1915

Three Modern Furnace Typ

core sands. Both synthetic and naturally-bonded sands are used. After the molds are dumped the sand goes through a reconditioning treatment and is then returned to the molders by way of an overhead system of conveyers and bins. The sand in use on the different molding floors is tested twice daily and the amounts of water and other additions to be used are varied according to the test results.

Two types of sand are used for cores, mixed in varying proportions and with varying quantities of binders and addition agents. All ingredients are weighed or measured, test cores are tested periodically in the foundry's laboratory, and a system of core inspection is maintained. A large proportion of the smaller cores is made on air-operated blowers.

In the cleaning room both sandblasting and steel shotblasting are used. A punch press trims off fins on many small castings and projections due to gates, formerly removed by grinding. Larger castings and those with heavy gates still require grinding. Before castings are delivered to the other shops they are rigidly inspected to avoid useless machining of any which might have visible external defects or are off dimensional requirements.

The recovery of metal from wastes, such as ashes, skimmings and the like, is an important operation. Waste materials are crushed in a ball mill and the fine grindings passed over a vibrating table, exactly of the sort so widely used in ore concentrators. This separates the metal from the mud in the mixture discharged by the mill.

Recovered metal of known composition is sent back in the foundry; other salvaged or mixed metal is sold to dealers, or smelted into ingot for analysis and re-use.

In conclusion, it is desired to emphasize the fact that in the modern plant every operation in the foundry and in related departments is under constant scrutiny in a concerted effort to improve working conditions, reduce costs and enhance the quality of the product. Much remains to be learned before all foundry operations can be brought under perfect control, but important progress is being made toward that end. The attainment of a reasonably complete technical control over the manufacture of brass and bronze castings is dependent upon an understanding of their complicated metallurgy and of the influence of impurities and minor constituents. Most of the problems to be solved are metallurgical or lie in closely related fields.

Fig. 9 — Line of Six Ajax-Wyatt Induction Furnaces for Melting Brass

Capacity of cylindrical furnace cavity is 750 lb.; from its bottom a channel containing molten metal loops down through a built-in transformer and thus becomes a single-turn secondary winding in which high energy heating currents are induced. Entire furnace is mounted on geared segmental trunnions and pours over the lip; charging is from an overhead trolley.

Typ… or Melting Copper Alloys

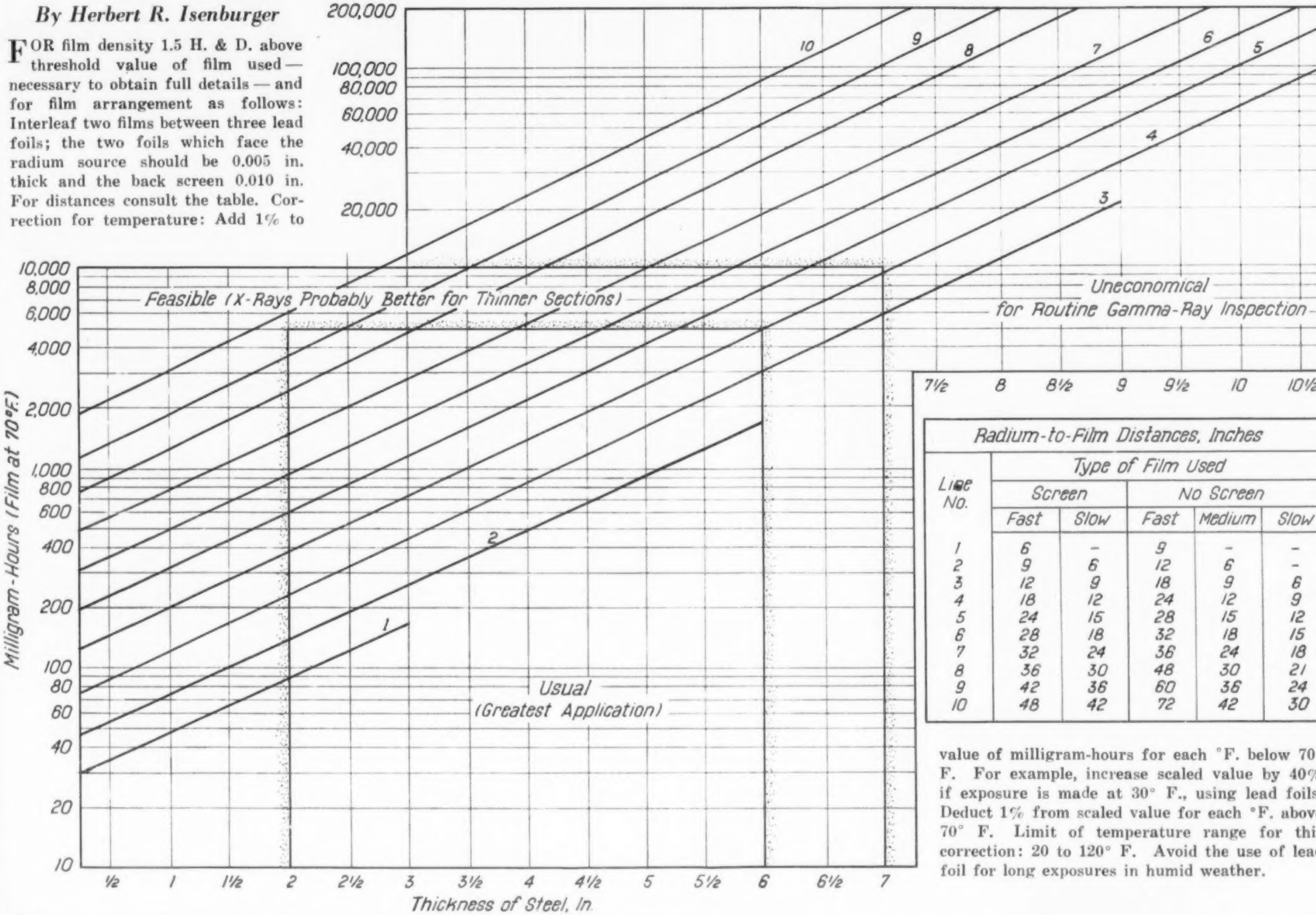
Furnace shell is like a drum and can be completely rolled over on its trunnions, although motion is ordinarily a rocking back and forth through an arc of 225°, thus keeping the charging door and pouring spout in the upper segment. Horizontal electrodes are centered through both ends; energy from the electric arc is absorbed by metal and brick lining, and transferred from lining to metal during the rocking process. Charging (1000 lb. of metal) is by chute entering opened charge-hole located above the spout in the pouring position shown in the view.

Fig. 10 — Four Detroit Rocking Furnaces for Melting High-Copper and High-Nickel Alloys

Exposure Chart for Radium Radiography

By Herbert R. Isenburger

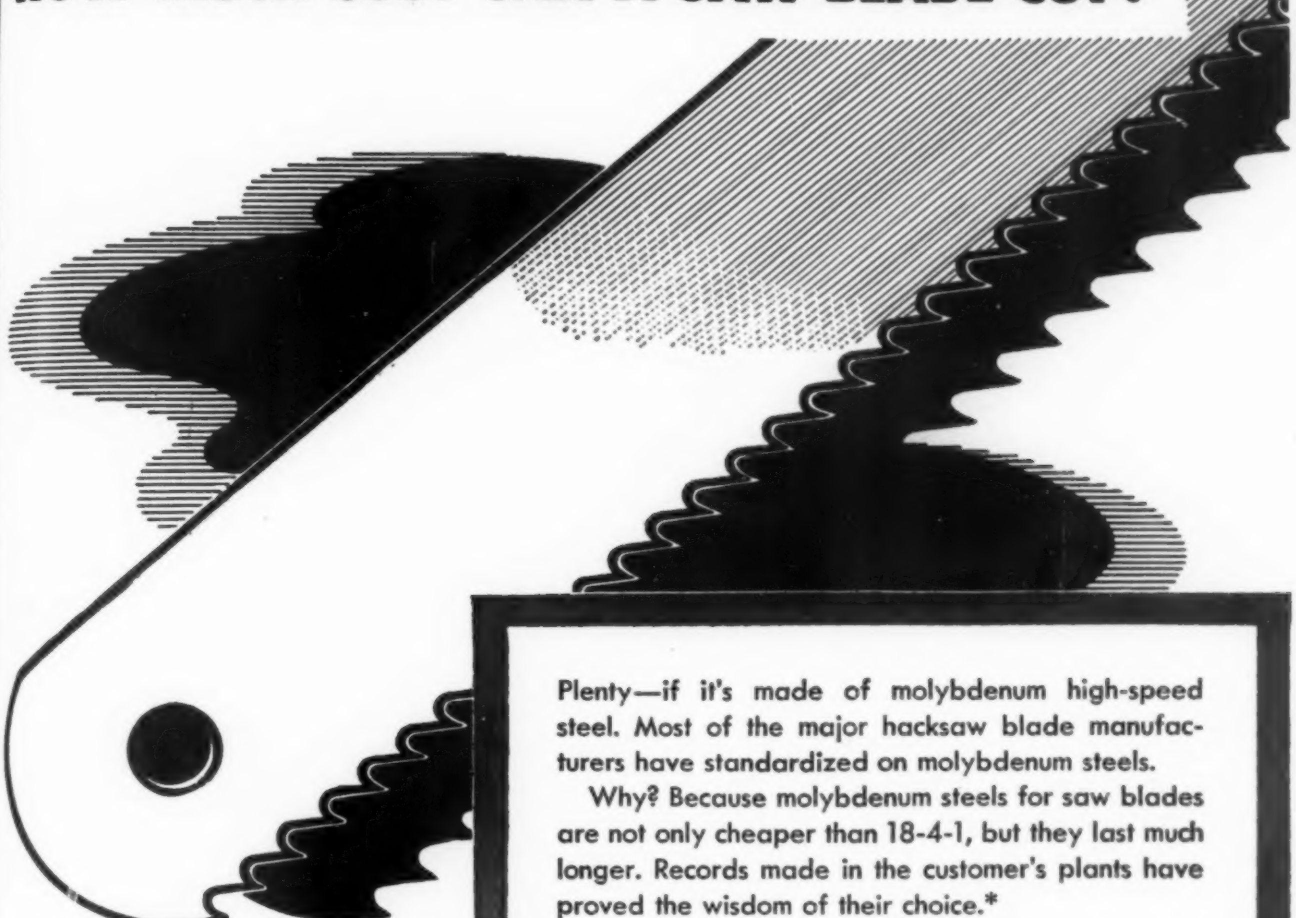
FOR film density 1.5 H. & D. above threshold value of film used — necessary to obtain full details — and for film arrangement as follows: Interleaf two films between three lead foils; the two foils which face the radium source should be 0.005 in. thick and the back screen 0.010 in. For distances consult the table. Correction for temperature: Add 1% to value of milligram-hours for each °F. below 70° F. For example, increase scaled value by 40% if exposure is made at 30° F., using lead foils. Deduct 1% from scaled value for each °F. above 70° F. Limit of temperature range for this correction: 20 to 120° F. Avoid the use of lead foil for long exposures in humid weather.



Radium-to-Film Distances, Inches

Line No.	Screen, Fast	Screen, Slow	No Screen, Fast	No Screen, Medium	No Screen, Slow
1	6	–	9	–	–
2	9	6	12	6	–
3	12	9	18	9	6
4	18	12	24	12	9
5	24	15	28	15	12
6	28	18	32	18	15
7	32	24	36	24	18
8	36	30	48	30	21
9	42	36	60	36	24
10	48	42	72	42	30

HOW MUCH COST CAN A SAW BLADE CUT?



Plenty—if it's made of molybdenum high-speed steel. Most of the major hacksaw blade manufacturers have standardized on molybdenum steels.

Why? Because molybdenum steels for saw blades are not only cheaper than 18-4-1, but they last much longer. Records made in the customer's plants have proved the wisdom of their choice.*

The same reasons—10¢ to 20¢ a pound saving over 18-4-1; more tools for the same gross weight of steel; better cutting performance; longer operation between regrinds—are back of the widespread adoption of molybdenum steels for all sorts of metal-working tools.

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Personals

Mike Lauriente ⊕ has accepted a position as metallurgist in the laboratory of the McCormick Works, Chicago, where he will be in charge of the annealing ovens in the malleable iron foundry.

After graduation from Virginia Polytechnic Institute, Howard R. Welsh ⊕ joined the Carnegie-Illinois Steel Corp., and was assigned to the metallurgical department of the Clairton works.

American Optical Co., Southbridge, Mass., announces the appointment of Carl H. Samans ⊕ as chief of the metallurgical section of their research laboratory, replacing W. J. Wrighton ⊕ who has retired after 27 years at this post.

Atlas Steels, Ltd., Welland, Ont., announces the appointment of Gilbert Soler ⊕ as works manager. Mr. Soler, formerly assistant general superintendent of the Steel & Tube Division of Timken Roller Bearing Co., and also previously with the Republic Steel Corp., joined the Atlas organization in 1946 as general superintendent.

R. W. Poulter ⊕, formerly master mechanic at John Deere Plow Works, has been transferred to Van Brunt Mfg. Co., Horicon, Wis., where he will be general superintendent.

Having received his M.S. at the University of Minnesota this past June, B. Krishnamurthy ⊕ is now in the metallurgical division of the Carnegie-Illinois Steel Corp. Before returning to India by the middle of next year, he proposed to take further training in Canada and England.

John P. Walsted ⊕ is now senior metallurgist in charge of the metallurgical division of the armor and projectile laboratory, Navy Proving Ground, Dahlgren, Va.

Thomas M. LaCrone ⊕, formerly chief metallurgist of the Lithium Co., has recently joined the sales organization of the Lindberg Engineering Co., with headquarters in Kalamazoo, Mich.

Frank R. L. Daley, Jr., ⊕ has transferred from development engineer of Chevrolet-Cleveland Div. to senior design engineer in connection with transmission development at Buick Motor Div., General Motors Corp., Flint, Mich.

Following graduation from Cornell University, Samuel I. Hyman ⊕ is at present a junior engineer in the development section, erection department, Babcock & Wilcox Co., Barberton, Ohio.

Eugene M. Kile ⊕, formerly design engineer at Goodyear Aircraft Corp., is now plant engineer at Star Drilling Machine Co., Akron, Ohio.

George K. Dreher ⊕, a past-chairman of the Milwaukee Chapter of the American Society for Metals, has taken the position of executive director of the Foundry Educational Foundation, Cleveland, an organization devoted to the development of engineering training for the foundry industry.

Wm. L. Rudin ⊕ has established a consulting service in Chicago specializing in nonferrous foundry problems with special emphasis on permanent mold design and applications.

Upon the transfer of Progressive Foundry Works to American Brake Shoe Co., V. H. Patterson ⊕ has been retained as sales metallurgist for the engineered castings division and his headquarters are in Rochester, N. Y.

Personals

A. F. Cone, formerly supervisor of quality control laboratory, Glenn L. Martin Co., has joined the Harnischfeger Corp. as a research engineer in the houses division, Port Washington, Wis.

Formerly assistant chief engineer for Consolidated Steel Corp. of Texas, Irving R. Seely is now chief engineer for the Kawneer Co. at Niles, Mich.

W. L. Batten joined the customer service department of Vanadium-Alloys Steel Co. in the capacity of metallurgist, upon graduation from Pennsylvania State College.

Metallurgical Engineers, Inc., Portland, Ore., announces that John W. Riches has joined their organization as engineering assistant. Mr. Riches is a recent graduate of State College of Washington.

Richard P. Witt, formerly metallurgical engineer at Goodspeed Machine Co., is now with Raytheon Mfg. Co., Waltham, Mass.

Richard M. Treco, formerly research metallurgist at the Hanford Engineer Works, has joined the research staff at the Massachusetts Institute of Technology.

Jack Lo Prete has left the Wolverine division of the Calumet and Hecla Copper Co. to become the president of the Spray-Coat Engineers, Detroit, Mich.

Richard L. Ahearn has joined the International Harvester Co., Louisville, Ky., following his graduation from the University of Notre Dame.

Maxwell Gensamer, formerly professor of metallurgy and head of the department of mineral technology of the School of Mineral Industries, Pennsylvania State College, has joined the research and technology department of Carnegie-Illinois Steel Co., Pittsburgh, as assistant to the director.

Robert Siglock is now in the engineering sales department of Hackney Iron & Steel Co., Enid, Okla.

H. M. Wies, formerly chief engineer of the Quaker Oats Co., Cedar Rapids, Iowa, is now superintendent of the Quaker Oats Co., Akron, Ohio.

The Wickwire Spencer Steel Div. of Colorado Fuel and Iron Corp. announces the appointment of F. A. Webber as chief metallurgist and J. H. Janssen as assistant chief metallurgist following the death of B. L. McCarthy, former chief metallurgist.

C. R. Tipton, Jr., formerly research assistant at University of Kentucky, is at present a research engineer in the foundry technology section at Battelle Memorial Institute, Columbus, Ohio.

On graduation from the University of Illinois, John L. Blazich joined the engineering department of the American Car & Foundry Co., St. Charles, Mo.

Morris E. Nicholson, who received his D.S. from Massachusetts Institute of Technology this past June, has accepted a position with the engineering research department of the Standard Oil Co. (Indiana) as a research engineer.

Albert J. Hohmann is now process engineer for tool design and production problems at Edmos Precision Casting Corp., Brooklyn, N. Y.

High Pressure Steam Piping*

THE STANDARD material for steam power plant in the past has been carbon steel. In view of the trend toward higher steam temperatures and pressures, it is useful to consider to what extent carbon steels will be satisfactory in the future. On the whole, many advantages can be gained by the use of alloy steels at 850° F. and up. Even at lower temperatures greater use can be made of alloy steels. Carbon-molybdenum steels, rather than carbon steels, have been perhaps the most widely used, so far, in pipe for superheated steam.

The chief qualities necessary for high temperature service are structural stability and resistance to deformation and corrosion. In addition, the material should be available at a reasonable cost with available facilities.

In weldability, carbon-molybdenum steel is perhaps the nearest approach to carbon steel. The room temperature mechanical properties of steam pipe of 0.135% C steel and 0.09% C, 0.50% Mo steel are similar. The superiority of carbon-molybdenum steel over carbon steel in suitability for carrying a load in service can be evaluated on the basis of the stress for 0.1% deformation in 100,000 hr. In terms of temperature, the working stress for carbon steel at 800° F. is about the same as that of carbon-molybdenum steel at 900° F., while the working stress of carbon steel at 900° F. approximates that of carbon-molybdenum steel at 950° F.

Lower elongation at fracture in long-time tests at temperature have been recorded for carbon-molybdenum than for carbon steel. With a total elongation at fracture as low as 5% for the carbon-molybdenum steel, it can not be safely assumed that it will be free from incipient cracking if the creep deformation is much in excess of 0.1%. In addition, too much attention should not be paid to the *total* elongation at fracture in creep tests, for the material may be in a dangerous condition with creep as low as 6% the total elongation at fracture.

Lower ductility of the carbon-

(Continued on page 648)

*Abstracted from "Carbon-Molybdenum Steel for Steam Pipes" by L. Rotherham, *Alloy Metals Review*, V. 5, March 1947, p. 2 to 5.

High Pressure Steam Piping

(Continued from page 646)

molybdenum steel may be related to the isolated cracking encountered in British power stations. This cracking, usually associated with regions of stress concentration or of local damage, appears to be of a different nature and much less serious than that encountered in the United States. On present evidence, it is concluded that a material with high ductility *before incipient cracking* (not necessarily a high total ductility at complete fracture) is to be preferred to one of low ductility; likewise, stress-raisers should be vigorously avoided. Fabrication or installation may produce internal or locked-up stresses approaching the yield point in magnitude. It is possible that the creep deformation necessary for the relief of these stresses might approach the total safe deformation. Usually such internal stresses are eliminated by normalizing, but occasionally stress relieving at subcritical temperature must be used. The comparative effect of these two treatments on the permissible creep deformation is not definitely known.

Little attention need be given to the surface stability of the carbon-molybdenum steel, since it is about the same as that of carbon steel. Changes in microstructure are more important. Graphitization on the scale noted in the United States has not occurred in pipe of British manufacture. Carbon steels graphitize more easily than carbon-molybdenum steels, but only those steels deoxidized with considerable aluminum show graphitization. Deoxidation with aluminum is not uncommon in Britain, but generally much smaller quantities are used than in the United States. This may account for the freedom from graphitization in England. Although the recommended addition of 0.5% chromium has been used in Britain, an estimation of its real value for high temperature service must await further power plant experience.

Carbon-molybdenum steel has very advantageous creep resistance in the higher steam temperature ranges which, in combination with its other properties, indicates it can be of great value for steam piping. On the other hand, its lower ductility makes it essential that care be exercised in fabrication and installation.